ACTION OF CHEMICAL SOLUTIONS ON BUD DEVELOPMENT: AN EXPERIMENTAL STUDY OF ACCLIMATIZATION.

BY JOHN W. HARSHBERGER, PH.D.

The phenomena of vegetation lend themselves to experimental study. This experimentation is necessary, because the laws which control the periodicity of plants can be determined only by altering the conditions under which such plants grow. Interest in the periodic growth of plants is perhaps keenest in the Spring, when everyone is observing, in a more or less detailed manner, the gradual awakenment of vegetation. The opening of shrub and tree buds has, as a result of this human interest, long engaged the attention of botanists. The phenomena of bud opening, and the laws to be deduced therefrom, have not been studied experimentally. Every student has been struck by the orderly sequence of the process in any particular district or climate. Each species seems to fill its allotted place in the line of bud development. The question arises, is this sequence due to heredity, to the character of the reserve food, or the disposition of this reserve food in the buds and twigs of the plant, or is it due solely to the climatic conditions, such as temperature and humidity? The experiments which follow will furnish data which it is hoped will contribute to the answer of the above questions. The only other experiments of a similar nature that have come to the writer's knowledge are those of DeCandolle, mentioned by Schimper[1] as follows: "Zweige von Holzgewächsen zeigen das gleiche Verhalten wie Samen. A. de Candolle trieb Zweige von Populus alba, Carpinus betulus, Catalpa bignoniæfolia [bignonioides?] und Liriodendron tulipifera die sich theils in Montpellier theils in Genf entwickelt hatten vom 4 Februar an in einen Raume dessen Temperatur während der Dauer des Versuches zwischen + 7° und +10° schwankte. Die Genfer Zweige entwickelten ihre Laub-knospen früher als die aus Montpellier stammenden."

Experiments of the First Year.

Eight species were studied the first year in which the experiments were conducted. Twigs from *Liriodendron tulipifera, Quercus palustris,*

[1] Schimper, A. F. W., *Pflanzengeographie auf physiologischer Grundlage,* p. 56.

Populus monilifera, Tilia americana, Magnolia conspicua, Æsculus hippocastanum, Salix babylonica and *Forsythia viridissima* were placed in various chemical solutions described below, and at the same time plants near the University were observed under more normal conditions out of doors. Twigs cut from these trees were placed in the chemical solution on March 1, 1907. Under each species will be mentioned the chemical solutions used and the reaction which took place. The date of the reaction will be given in each particular case. The species of the first year's experimentation are arranged in the order of their response. The plants were kept in a greenhouse where the temperature range was about 25 degrees. At night the temperature descended to 65° F., while on sunny middays it rose as high as 90° F.

Forsythia viridissima.—The following chemical solutions were used with this species. One per cent. chromic acid filled several of the bottles; ordinary stock picric acid diluted four times with water; ammonium nitrate (two grams) dissolved in 200 cubic centimeters of water; five decigrams of sodium chloride in fifty cubic centimeters of water; five drops chemically pure nitric acid in fifty cubic centimeters of water; menthol water; two bottles filled with 800 cubic centimeters of filtered water; two grams ammonium sulphate in 600 cubic centimeters of water; 100 cubic centimeters of ether in 500 cubic centimeters of water; 200 cubic centimeters of chemically pure ammonium hydrate in 1,000 cubic centimeters of water; a saturated solution of corrosive sublimate in 1,000 cubic centimeters of water; ten drops of chemically pure hydrochloric acid in fifty cubic centimeters of water.

One week after the experiments were begun buds of this species showed a reaction. The most marked was with the ammonium hydrate solution when, on March 8, it was found that all of the buds above the middle ones were well opened, but the leaves remained tightly folded. There was a steady advance in this solution until March 20. On March 11 the flower buds were ready to open, and on March 15, four days later, the buds were expanded, while on March 18 the flowers had withered and a few green leaves had appeared. After March 25 there was no advance, and on March 28 the twigs were dead. Response was shown on March 8 by the twigs in picric acid, ammonium nitrate, sodium chloride, hydrochloric acid, ammonium sulphate, ether water, corrosive sublimate and pure water. The most marked response was in the solution with five drops of hydrochloric acid, where the buds had burst, and in the picric acid, where the three topmost buds had burst. The response in the other cases was shown by an easement of the buds. In the pure water the buds

were green. On March 8 no reaction was shown by the twigs in the chromic acid, nitric acid, menthol water and one bottle of filtered water. In fact the twigs in the nitric acid did not respond and were dead by March 20. The buds, however, in the menthol water, chromic acid and filtered water had responded on March 11. The subsequent history of the twigs in the different solutions is as follows:

Chromic Acid.—March 11: The buds of the two upper nodes were developed. March 15: The two topmost buds were expanded, but the leaves were still folded. March 18: The leaves of the top pair of buds were fully expanded, with the terminal bud one and a half inches long. March 25: No advance.

Picric Acid.—March 11: Upper buds were green. March 15: A few end buds were green, but not opened. March 18: Upper buds burst, leaves green. March 20: Leaves hardly unfolded. March 25: No advance. March 28: Leaves hardly unfolded. March 25: No advance. March 28: Twigs dead.

Ammonium nitrate.—March 11: All of the buds were burst and some of the leaves were expanded. March 15: Nearly all of the buds showed leafy branches one and a half inches long, with two to three pairs of leaves expanded. March 18: All of the green leaves were spotted and unhealthy looking. March 20: All of the expanded leaves were dead, and on March 28 all of the twigs were dead.

Sodium chloride.—March 11: The three upper buds were enlarged and ready to burst. March 15, March 18, March 20, March 25: No advance in the development of these buds took place, and on March 28 the twigs were dead.

Hydrochloric Acid (five-drop solution).—March 11: The buds were burst open, but the leaves were still folded together; only the lowermost leaf was expanded. March 15: The upper two pairs of buds had grown to a branch two inches long, with four pairs of opposite leaves unfolded. March 18, March 20: All leaves of the branches expanded. March 25, March 28, April 1: No advance. April 5: Twig dead.

Menthol Water.—March 11: Middle buds burst. March 15: Three buds were green, but not fully opened. March 18, March 25, March 28, April 1: No advance. April 5: Twig dead.

Filtered Water (*A*).—If the twig in this experiment is contrasted with the twig in the other bottle of water, it is evident that its vitality must have been impaired in some way before the experiments began, hence the results obtained. On March 8 there was no response, as in the other case March 11. The middle and lower buds had burst, the leaves were flat but still erect. March 15: All of the buds had devel-

oped into leafy branches two and a half inches long. March 18: All of the branches measured two and a half inches long. March 20: Slow advance. March 25, March 28, April 1: No advance. April 5: Twigs withered.

(*B*) March 11: Leaf buds eased, two flower buds were ready to open. March 15: All of the flower buds were open, leaf buds one-half inch long. March 18: All of the branches were green and two inches long. March 20: The green branches were slowly growing. March 25, March 28: The twigs and leaves were making rapid growth. April 1, April 5, April 13: The growth continued.

Ammonium sulphate.—March 11: One flower bud showed signs of opening. March 15: Three flower buds advanced to stage of the first, but still tightly closed, no leaf buds open. March 18, March 20, March 25: No advance. March 28: Twig dead.

Corrosive sublimate.—March 11: Lower pair of leaves in each of the leaf buds were expanded. March 15: Branches were two inches long and three pairs of leaves expanded. March 18: Branches two to two and one-half inches long, flowers all withered. March 20: Leaves of twig all flat. March 25: Leaves were all expanded and had grown in size. March 28: Leaves began to wither. April 1: Twigs unhealthy.

Hydrochloric Acid (ten-drop solution).—March 11: Middle buds of twig eased. March 15: Buds were three-quarters of an inch long, leaves were not unfolded. March 18: Three buds were burst, but on March 20 no advance in these buds was shown. March 25, 28, April 1: No advance in twig. April 5: Twig dead.

Magnolia conspicua.—Only two solutions were used in experimenting with the twigs of this tree. Two grams of ammonium nitrate were dissolved in 200 cubic centimeters of water. Filtered water was also used as a control. On March 8 the twigs did not show response in either liquid. The first response was shown on March 11.

Ammonium nitrate.—March 11: The large terminal bud was burst, white petals shown at the base. March 15: Bud opened, but no additional development. March 18: No advance. March 20: Terminal buds unhealthy. March 20: All the buds were dead.

Filtered Water.—March 8: No response. March 11: Flowers fully open with the petals reflexed, but the stamens still closed. March 15: Flower buds withered. March 18: First foliage leaf expanded. March 20: The twig was a little more advanced. March 25, March 28, April 1: Twig was dead.

Æsculus hippocastanum.—Five solutions were used with the horse chestnut, viz., five drops of hydrochloric acid in fifty cubic centimeters

of water; five drops of chemically pure nitric acid in fifty cubic centimeters of water; three bottles contained filtered water.

Hydrochloric Acid.—March 11: Buds not burst, but resin abundant and more fluid. March 15, March 18, March 20: No change reported in the record of this branch. March 25: Bud burst at tip. March 28: Bud nearly fully burst, leaves still tightly folded. April 1, April 5: No change. April 13: Twig dead.

Filtered Water (*A*).—March 11: Terminal bud very resinous. March 15: Terminal buds well expanded. March 18: Large buds well expanded, but leaves still tightly folded. March 20: Terminal buds with leaves still erect. March 25: Leaves of terminal bud distinct and horizontal, but segments still folded together, covered with rusty hairs. March 28: Leaflets beginning to separate. April 1, April 5: No advance. April 13: Twig dead.

(*B*) No response on March 8 and March 11. March 15: One lateral bud with woolly leaves showing. March 18: Leaves of two lateral buds flattened out horizontally. March 20: All of the leaves of the lateral buds placed horizontally. March 25: Leaves began to lose their tomentum. March 28: Leaflets began to separate. April 1, April 5: No change. April 13: Twig dead.

(*C*) March 11: Buds became sticky, resinous, inner scales began to show between the outer scales. March 15: Buds well expanded, but not fully burst. March 18: Buds burst, young leaves still folded together. March 20: Bud fully open, one leaf horizontal. March 25: Leaves all horizontal, covered with tomentum. March 28: Leaflets still folded together. April 1: Leaves somewhat withered.

Populus monilifera.—The following chemical solutions were used in experimenting with the twigs of the Carolina poplar: Chromic acid, one per cent.; filtered water; five decigrams of sodium bicarbonate in fifty cubic centimeters of water; five decigrams of sodium chloride in fifty cubic centimeters of water; five drops of chemically pure sulphuric acid in 100 cubic centimeters of water; ten drops of chemically pure hydrochloric acid in fifty cubic centimeters of water; twenty drops of chemically pure sulphuric acid in 100 cubic centimeters of water; menthol water; filtered tap water; 100 cubic centimeters of ether in 500 cubic centimeters of water; 200 cubic centimeters chemically pure ammonium hydrate in 1,000 cubic centimeters of water; two grams of ammonium sulphate in 600 cubic centimeters of water; saturated corrosive sublimate solution diluted in 1,000 cubic centimeters of water.

No response was noticed in any of the twigs on March 8 and March 11, except in the case of the twig in ether water which showed a slight easement of the upper buds. This stimulus was only a temporary one, because on March 11 no enlargement was noticeable. On March 15, the twigs in water, menthol water, ether water, ammonium hydrate, ammonium sulphate and corrosive sublimate had responded and the extent of this response will be indicated in what follows. It should be noted, however, that the buds on the twigs on March 15 in the ammonium hydrate solution had burst and the leaves were about to unfold, while the buds of the twigs in the filtered water, in the corrosive sublimate and in the ammonium sulphate were just beginning to burst open.

Chromic Acid (one per cent).—No response whatever on any of the dates.

Water (*A*).—March 15: Buds enlarged and green, but not open. March 18: Large buds burst, leaves about to unfold. March 20: Lateral buds open, one leaf began to unfold. March 25: Lateral buds with first leaves partly unfolded, terminal buds burst. March 28: Terminal buds fully expanded, one or two leaves unfolded. April 1: Two leaves of lateral bud expanded. April 5: No advance. April 13: Leaves broad, bright green, twig fresh.

Sodium bicarbonate.—No reaction.

Sodium chloride.—No response, twigs eventually killed.

Sulphuric Acid (five-drop solution). No response until March 18 when the buds were slightly enlarged. March 20: A slight additional enlargement. March 25, March 28, April 1: No advance. On April 13 the twig was dead.

Hydrochloric Acid.—No response.

Sulphuric Acid (twenty-drop solution).—No reaction, eventually killed.

Menthol Water.—March 15: Terminal bud enlarged, but not open. March 18: Terminal bud burst, but the leaves are tightly folded. March 25: Terminal bud with bud scales separated, leaves not expanded. March 28, April 1, April 5: No advance. April 13: Twigs dead.

Filtered Water (*B*).—March 15: Buds enlarged. March 18: Buds burst. March 20: Buds well open, first leaf about to expand. March 25: Leaves of terminal bud all fully expanded. March 28: Leaves of upper two buds flattened. April 1: Green leaves fully developed. April 5: Adventitious roots appeared, leaves fully matured.

Ether Water.—March 15: Buds large and very green, about to burst.

March 18: Two lateral buds with leaves expanded, most advanced developed in all the solutions. March 20: Some buds fully open, with one or two leaves flattened horizontally. March 25: No advance. March 28: Majority of twig leaves beginning to unfold. April 1: Leaves were all fully expanded. April 13: Twig dead.

Ammonium hydrate.—No response until March 15 when one of the lateral buds had burst and leaves were about to unfold. March 18: Leaves nearly unfolded. March 25, March 28: No advance. April 1: Twigs dead.

Filtered Water (*C*).—No response until March 15 when buds were found enlarged. March 18: Buds expanded and leaves flattened out. March 25: Terminal and lateral buds with leaves fully expanded. Rapid growth of this twig continued until April 13 when the experiments were concluded.

Ammonium sulphate.—March 15: Large buds about to open. March 18: Leaves pretty well expanded. March 20: One leaf of lateral bud fully expanded, three others almost so. March 25: Leaves of topmost lateral bud nearly expanded. March 28: No advance. April 1: All of the twigs had gone bad.

Corrosive Sublimate.—March 15: Buds enlarged. March 18: Buds burst and about to unfold. March 20: Leaves of terminal bud well unfolded. March 25: Some of the leaves expanded. March 28: Buds fully burst, two or three of the leaves were green and flat. April 1: Not much advanced, twig still fresh. April 1: Leaves fresh and green, broadly expanded. April 13: Twig dead.

Liriodendron tulipifera.—The chemicals used in the experiments with the tulip poplar were as follows: Five decigrams of sodium chloride dissolved in fifty cubic centimeters of water; filtered water; five drops of chemically pure sulphuric acid in 100 cubic centimeters of water; five drops of chemically pure hydrochloric acid in fifty cubic centimeters of water; five drops chemically pure nitric acid in fifty cubic centimeters of water; twenty drops chemically pure sulphuric acid dissolved in 100 cubic centimeters of water.

The twigs did not respond in any of the above-mentioned solutions until March 11, when those in the twenty-drop solution of sulphuric acid and in one bottle of filtered water showed a slight separation of the two outer bud scales. The record for the other twigs is somewhat unusual and is here given.

Sodium chloride.—Absolutely no response.

Filtered Water (*A*).—The twigs did not respond until March 18,

when two of the lateral buds split open, the inner pair of green stipules visible. March 25: A lower lateral bud with one leaf expanded, another leaf was folded. March 28: Another lower lateral bud with two leaves out, one only expanded. April 5: Terminal bud casting off the outer brown stipules, one leaf unfolded. April 13. Twig dead.

(*B*).—Twig dead, no response.

(*C*).—March 11: Bud split open. March 15: First inner pair of green stipules visible. March 18: Buds well opened, but first leaf not unfolded. March 20: First leaf expanded. March 25: Terminal and lateral buds each showing one green leaf. March 28: Leaves flat, buds rapidly expanding. April 1: Twig gone bad.

Sulphuric Acid (five-drop solution).—No response.

Sulphuric Acid (twenty-drop solution).—March 11: Two upper buds with outer stipular scales slightly eased apart. March 15: Scales more eased apart. March 18: Buds burst. March 20, March 25, March 28, April 1: No advance. April 13: Twig dead.

Hydrochloric Acid (five drops). No response.

Nitric Acid (five drops).—No response.

Salix babylonica.—The chemicals used with the weeping willow were: Chromic acid, one per cent.; two grams ammonium nitrate in 200 cubic centimeters of water; five decigrams of sodium bicarbonate in fifty cubic centimeters of water; five decigrams of sodium chloride dissolved in fifty cubic centimeters of water; ten drops of chemically pure hydrochloric acid in fifty cubic centimeters of water; filtered water; 100 cubic centimeters of ether mixed with 500 cubic centimeters of water; 200 cubic centimeters of chemically pure ammonium hydrate in 1,000 cubic centimeters of water; picric acid; saturated solution of corrosive sublimate. The results obtained in this series of experiments possess considerable interest.

Chromic acid, ammonium nitrate, sodium bicarbonate, sodium chloride, ether water, ammonium hydrate, picric acid, corrosive sublimate gave no response.

Filtered Water (*A*).—No response was shown until March 18 when the buds of the female spike opened. March 20: Roots well developed, pistillate spikes one inch long. April 1, April 5: Twig still continued its growth. April 13: Twig withered.

(*B*) First response on March 11 when secondary roots began to form, no bud reaction. March 15: Pistillate spikes one inch long; roots pink, three inches long, numerous. March 18: Leaf buds open, first green leaves expanded. March 20: Pistillate spikes two inches

long, root four inches long. March 25: Roots long and curved about the bottom of the bottles, leaves elongated, dark green, three to four inches long. March 28: Green branches four inches long, leaves flat, roots numerous. April 1: Two lateral branches green and four inches long. April 5: Shoots eight inches long. April 13: Twig dead.

(*C*) March 11: Secondary roots appeared; no bud reaction. March 18: Leaf bud burst. March 20: Leaves well expanded, roots well developed. March 25: Leaves advancing rapidly to maturity. March 28: Leafy branches, rapidly growing. April 1, April 5: Growth continued. April 13: Leaves were sere.

Tilia americana.—The chemical solutions used in experimenting with the twigs of the linden were: chromic acid, one per cent. solution; stock picric acid in four times its volume of water; five decigrams of sodium bicarbonate dissolved in fifty cubic centimeters of water; filtered water as a control; ten drops of hydrochloric acid in fifty cubic centimeters of water; 100 cubic centimeters of ether in 500 cubic centimeters of water; saturated corrosive sublimate in one liter of water. There was no response shown in any of the twigs until March 15. The twigs in the chromic acid, ten-drop hydrochloric acid solution and in ether water showed no response during the entire course of the experiments. The record obtained from the other twigs is as follows:

Picric Acid.—March 15: Bud scales slightly eased apart. March 18: Terminal bud burst, three-quarters of an inch, green. March 20: Terminal bud expanded, upper part of the folded leaves seen within. March 25: Terminal bud burst, leaves out of the bud, but folded together. March 28: Leaves brown and nearly dead. April 1: Twig dead.

Sodium bicarbonate.—March 15: Inner scales of terminal bud pushed beyond the outer scales one-sixteenth of an inch. March 18: One-fourth of an inch beyond, terminal bud burst, no leaves expanded. March 25, March 28: No further advance.

Filtered Water (*A*).—March 15: Two larger bud scales eased apart. March 18: Buds burst, green spire one-fourth of an inch long. March 25: Terminal bud green, spire-shaped. March 28: Same condition as on previous day. April 1: No further advance, water later evaporates, ending the development of this twig.

(*B*) March 15: Terminal bud nearly burst. March 18: Buds expanded, three-quarters of an inch green. March 20: Upper buds burst, sides of folded leaves seen. March 25: Two leaves of the termi-

nal bud fully expanded. March 28: The twig was found dead, because the water had evaporated from the jar.

Corrosive Sublimate.—March 15: Bud scales eased. March 18: Buds nearly all burst. March 20: Half of the folded green leaves seen in the partially open bud. March 25: One to three leaves were found fully expanded. March 28: All of the buds were burst, with one to three leaves fully expanded, flat and large. April 1: Twigs gone bad.

Quercus palustris.—The chemicals used were: Two grams of ammonium nitrate dissolved in 200 cubic centimeters of water; five decigrams of sodium bicarbonate dissolved in fifty cubic centimeters of water; five decigrams of sodium chloride dissolved in fifty cubic centimeters of water; 200 cubic centimeters of chemically pure ammonium hydrate dissolved in one liter of water; saturated solution of corrosive sublimate in one liter of water; two water control experiments were inaugurated.

The twigs placed in the ammonium nitrate, sodium bicarbonate, sodium chloride, ammonium sulphate, and ammonium hydrate solutions made no response by the opening of the buds. Those, however, in the solution of corrosive sublimate showed signs of response on March 25, when the terminal bud showed signs of elongation. On March 28, three days after, the terminal bud had burst and the leaves were ready to unfold. On April 1 the twigs began to show signs of going bad. In water the response was more marked than in the corrosive sublimate solution, for on March 25 the terminal bud had burst, but the leaves were still enclosed in the stipular scales. On March 28 the leaves had nearly expanded, and on April 1 the leaves were fully expanded and the new shoots 100 to 127 millimeters long.

Summary of the Experiments of the First Year.

The experiments conducted the first year with twigs in various solutions throw considerable light upon the conditions which influence the flow of sap in plants. Strasburger set the cut ends of trees in tubs containing copper sulphate solution. He found that the poison ascended to the leaves a distance in the tallest trees of twenty-one meters. If such a violent protoplasmic poison ascends the trunks of trees, it is clear that they must kill all of the cells lying in the path of its ascent. Strasburger concluded that the living cells of the stem were not necessary to the ascent of the sap, as a result of the above-mentioned experiment with copper sulphate. Strasburger also killed portions of the stems of living trees by heat, and yet the upper living

and leafy portion was found to remain turgid for a few days. Another experiment, which was held to negative the theory of protoplasmic activity, was that in which boiling water was poured on the root, when the plant continued to respire in spite of the roots having been killed.

These experiments of Strasburger are negatived by the experiments with the twigs in the various chemical solutions previously described. As before indicated, the response of the twigs in the most susceptible instance did not take place until a week after the twigs were placed in the chemical solutions. After the first response, the opening of the buds progressed steadily until the leaves had fully expanded. In some instances the branch grew considerably in length after the opening of the buds had started. As the experimental data prove, many twigs did not respond but were killed outright, as illustrated by the twigs of the Carolina poplar, *Populus monilifera*, in the ten-drop hydrochloric acid solution, or as in the case of *Quercus palustris* in the sodium bicarbonate, sodium chloride and ammonium hydrate. Many twigs which responded at first by the enlargement or even bursting of the buds afterwards made no advance and were eventually killed, and ultimately most of the twigs not in water, but with their ends immersed in the chemical solutions, died after the buds had dried up or the leaves had wilted. This seems to indicate that the chemicals first acted as a stimulus on the twigs; this was followed by the ascent of water, by the suctional activity of the living cells of the twig and bud, while the poisons lagged behind. As long as any of the cells remained alive in the upper part of the twigs and in the buds they maintained their suctional activity. Bose,[2] by a series of elaborate and painstaking experiments, has shown after the administration of a poison at the cut end of a branch or petiole that successive zones are killed one after another, and that the death of a point below does not stop the suction above. He says: "It is evident that the application of poison at the root or cut end of a stem does not in general arrest suction until the whole plant is killed." The records of his newly devised shoshungraph indicate that the final arrest occurs after an appropriately long period. That a poison can easily pass through killed tissue owing to the suctional response of cells higher up, Bose proved in his experiments on *Desmodium*, when he placed the cut end of a petiole in copper sulphate solution. In this case there are areas which during the ascent of the poison react visibly by the motile indications of the

[2] Bose, Jagadis Chunder, *Plant Response as a Means of Physiological Investigation,* 1906, p. 385.

pulvini of the inserted lateral leaflets. Bose by his experiments proved that the ascent of sap is brought about, not by any localized group of cells in a particular region, but by cells which extend throughout the length of the plant. Even after some of these have died, therefore, by the access of the poison, those above are still active, and will continue to exhibit suction until they in their turn are finally killed. It is thus evident that the movement of ascent cannot be completely abolished until the poison has reached effectively the very top. As all the living cells are actively concerned in the work of suction, this conveyance of poison to the top of the plant is what was to have been expected. Only after such conveyance indeed could permanent arrest possibly take place. Bearing these facts in mind, the action of the chemicals on the various twigs used in my experiments become very much simplified, and, instead of being very complex and unintelligible phenomena, became reducible to one or two simple kinds of activity.

Another important principle to be deduced from the experiments of the first and also of the second year is, that the experimenter is unable to disturb the natural sequence of bud opening by the stimulus imparted to the twigs by the various chemical solutions. In only one or two instances did the chemical seem to react upon the buds and cause their enlargement out of the usual sequence. These cases were with *Forsythia viridissima* twigs in the ammonium hydrate solutions and in the five-drop hydrochloric acid solution. The response was appreciably earlier and greater than with the twigs in filtered water alone, or in the chemical solutions. The *Populus monilifera* twigs in the ether water responded seven days in advance of the other twigs placed under various experimental conditions. The results obtained seem to indicate that the chemicals do not influence either the time or the order of the response, but that this time and sequence depend upon some factor not directly influenced by the environment or by the experimental conditions. One then looks to the hereditary influence which determines the time and the sequence of bud development. Under hereditary influence we may include the minuter structure of the plant which determines what the character of the response must be. Perhaps it is a structural preparedness and the character of the reserve food which determines the sequence of bud development. To determine this point a study was made of the microscopic anatomy of the experimental twigs. These are described in the order in which the twigs responded in their bud development. The twigs were cut on March 13, 1907, before the advent of Spring, which occurred on March 30 and 31.

(1) FORSYTHIA VIRIDISSIMA.—The iodine test showed the pith cells crowded with starch, as also the cortex cells between the bast fibers, as also the medullary ray cells. Fehling's test gave no reaction.

(2) MAGNOLIA CONSPICUA.—On treating the sections with iodine starch was found in the medullary ray cells and not any in the cortex. Fehling's test for sugar gave no reaction.

(3) ÆSCULUS HIPPOCASTANUM.—Starch occurs in the protoxylem region, in the inner part of the medullary rays. No starch was found in the cortex cells and no reaction was produced with Fehling's solution.

(4) POPULUS MONILIFERA.—The iodine test showed the presence of starch in the cortex. Fehling's test for sugar gave no result.

(5) LIRIODENDRON TULIPIFERA.—Starch is present in the younger and older portions of the stem in the cortex cells. No sugar reaction.

(6) SALIX BABYLONICA.—Iodine showed the presence of starch in the cortex cells and medullary ray cells. No starch was found in the pith. Fehling's sugar test was negative.

(7) TILIA AMERICANA.—Small starch grains were found in the cortex of a one-year old stem. No starch was seen in the cortex of old stems. In water the sections became strongly mucilaginous. Fehling's solution gave no reaction.

(8) QUERCUS PALUSTRIS.—Starch was found in the pith, medullary ray cells and in the wood-parenchyma cells. No starch was detected in the cortex. Fehling's solution gave no starch reaction.

As far as these microscopic studies throw light upon the state of the plant's preparedness, they seem to support the view that the more prepared a plant is and the more responsive its protoplasm is to the influence of external conditions the earlier is its response. For the response of *Quercus palustris* with deep-seated starch is much more sluggish than the response of the twigs where the starch occurs in the cortex. This relationship of response to the position of the reserve food should not, however, be pushed too far, as the protoplasm of the twigs and that of the cells of the preformed buds may be influenced without any transformation of the reserve supplies of food. We do find, however, a sequential development of the buds and, as far as the experiments go to show, that sequential development is not disturbed by the chemicals that are used. The course of bud development, therefore, depends upon the state of preparedness of the twig and bud, and not on the environmental conditions which surround the plants. Heat is the great factor which determines the opening of the buds. If the plant has the requisite supply of moisture, heat will accelerate the

opening of buds; but buds of different species of plants if exposed to the same temperature preserve the order of their bud development; but the time interval is very much lessened if the amount of heat is increased. This was exemplified by a double climbing white rose growing against the side of a house with a chimney placed in the outside wall. The heat of the chimney caused the buds over the chimney bricks to open at least a week or ten days before those on the rest of the bush showed any signs of development. All of the buds in the rosebush were equally prepared to open, but only those did so which received the stimulating effect of the heated brick surface.

Experiments of the Second Year.

The second year of experimentation began with a plan for the enlargement of the scope of the work of the previous year. In order to test the question whether chemical solution could alter the sequence of bud development if the buds were obtained from different geographic localities, and in order to test whether the twigs obtained from southern latitudes would or would not respond more or less quickly than the twigs from northern latitudes to the new environmental conditions, a circular letter was addressed to all of the agricultural experiment stations and to a few private individuals in the forest-covered portion of the eastern United States from the Gulf States to Maine. The letter read as follows:

> *My dear Sir:*—In continuation of a study which I have begun on the influence of chemicals on the opening of buds, I write to ask if you will supply me with twigs of one or several of the following varieties of fruit trees: *apple*: Baldwin, Early Harvest, Maiden Blush, Red Astrachan, Winesap, York Imperial; *cherry*: Black Heart, Governor Wood, Morello; *peach*: Early Crawford, Late Crawford, Oldmixon (free); *pear*: Duchess de Angouleme, Bartlett, Clapp Favorite, Flemish Beauty, Kieffer, Seckel. These twigs I should like cut so as to show the last three years of terminal growth. In addition I should like twigs of the same age of *Quercus palustris* (the pin oak), *Liriodendron tulipifera* (the tulip poplar), *Populus monilifera* (the Carolina poplar), *Acer rubrum* (the red maple), *Æsculus hippocastanum* (the horse chestnut), *Forsythia viridissima*, *Tilia americana* (the linden), *Magnolia conspicua* (Yulan magnolia). If not too much trouble please send them so as to reach me on January 15, 1908, when I expect to start all of the twigs received.

This letter is printed in full because it describes the character of the material upon which the experiments were made. Replies were received from eleven institutions widely enough separated from each other, so as to make the results obtained of interest in connection with the acclimatization of plants and with regard to the influence of heredity on the general method and time of bud development. The institutions which made reply and the names of the tree twigs sent from

Auburn. Alabama	Lexington, Kentucky	Lafayette, Indiana	Lansing, Michigan	Amherst, Massachusetts	Storrs, Connecticut	Geneva, New York	Ithaca, New York	New Brunswick, New Jersey	College Park, Maryland	Pennsylvania State College	University of Pennsylvania	
		×	×	×	×	×		×		×		Baldwin Apple.
×						×			×	×		Early Harvest Apple.
×		×	×		×	×			×			Maiden Blush Apple.
×					×	×			×	×		Red Astrachan Apple.
×		×				×						Winesap Apple.
×		×		×	×	×			×			York Imperial Apple.
												Black Heart Cherry.
									×			Governor Wood Cherry.
				×				×		×		Morello Cherry.
×						×			×			Early Crawford Peach.
		×							×			Late Crawford Peach.
	×	×							×			Oldmixon Free Peach.
			×		×	×			×		×	Duchess de Angouleme Pear.
			×	×	×	×		×				Bartlett Pear.
			×		×			×				Clapp Favorite Pear.
		×	×		×			×				Flemish Beauty Pear.
×		×	×		×		×	×	×	×		Kieffer Pear.
			×	×		×	×	×	×		×	Seckel Pear.
			×							×	×	*Quercus palustris* (Pin Oak).
×	×	×	×		×					×	×	*Liriodendron tulipifera* (Tulip Poplar).
×	×	×	×		×		×	×		×	×	*Populus monilifera* (Carolina Poplar).
×		×	×		×	×	×	×		×		*Acer rubrum* (Red Maple).
	×	×	×				×	×		×	×	*Æsculus hippocastanum.*
			×		×	×	×	×	×	×	×	*Forsythia viridissima.*
	×	×			×		×	×		×	×	*Tilia americana.*
		×						×			×	*Magnolia conspicua.*

each station are given in the accompanying table. It will be seen that the material came from as far south as Alabama and as far north as Massachusetts, and that the twigs sent by the correspondents were abundant enough to represent, in many cases, the entire geographic range of the variety studied. Thus the Red Astrachan apple twigs came from Pennsylvania State College; College Park, Maryland; Geneva, New York; Storrs, Connecticut, and Auburn, Alabama.

Bundles of twigs were sent by express in boxes or protected by burlap. Upon their receipt at the University they were kept in a light, cool, airy cellar until all of the packages had been received. The experiments, as far as practicable, were started at the same time, viz., on the afternoon of January 22, 1908, and on the morning of January 23, 1908. The bottles with chemical solutions had been prepared previously. The jars with the twigs were placed in a greenhouse the temperature of which ranged from about 70° F. at night to 90° or 95° in the daytime. The latter temperature was reached with a bright midday sun. The observation continued uninterruptedly from January 23, 1908, to March 14, when the experimentation virtually stopped. Only one change was made in the fluids, viz., on February 14, 1908, when the evaporated water was resupplied, without the addition of any fresh chemical substance.

The chemical solutions used were made as follows:

Corrosive sublimate.—Strong solution: Ten grams in 850 cubic centimeters of water. Weak solution: Five grams in same amount of water.

Copper sulphate.—Strong solution: Ten grams in 850 cubic centimeters of water. Weak solution: Five grams in same amount of water.

Sodium chloride.—Strong solution: Ten grams in 850 cubic centimeters of water. Weak solution: Five grams in same amount of water.

Ammonium nitrate.—Strong solution: Ten grams in 600 cubic centimeters of water. Weak solution: Five grams in 600 cubic centimeters of water.

Ammonium oxalate.—Strong solution: Ten grams in 600 cubic centimeters of water. Weak solution: Five grams in same amount of water.

Ammonium oxalate.—Strong solution: Ten grams in 600 cubic centimeters of water. Weak solution: Five grams in same amount of water.

Potassium chloride.—Strong solution: Ten grams in 900 cubic centi-

meters of water. Weak solution: Five grams in same amount of water.

Sodium bicarbonate.—Strong solution: Ten grams in 900 cubic centimeters of water. Weak solution: Five grams in the same amount of water.

Potassium bisulphate = Acid sulphate.—Strong solution: Ten grams in 850 cubic centimeters of water. Weak solution: Five grams in the same amount of water.

Hydrochloric Acid.—Strong solution: Ten cubic centimeters in 800 cubic centimeters of water, only one-half of this liquid being used in the experiment. Weak solution: Five cubic centimeters in 800 cubic centimeters of water, only one-half of this liquid was used.

Acetic Acid.—Strong solution: Ten cubic centimeters in 800 cubic centimeters of water, one-half this quantity of liquid was used. Weak solution: Five cubic centimeters in 800 cubic centimeters of water used in one-half the amount of liquid.

Nitric Acid.—Strong solution: Ten grams used prepared as above. Weak solution: Five grams as above.

Chromic Acid.—Strong solution: Ten cubic centimeters of four per cent. acid in 500 cubic centimeters of water, one-half of the amount of liquid being used. Weak solution: Five cubic centimeters of four per cent. acid in 500 cubic centimeters of water, liquid used in half amounts.

Besides the use of chemical solution water controls were instituted, the twigs from each station being placed in a separate jar of water. Thus there were jars for the twigs from the agricultural experiment stations mentioned above. Each of the twigs (some 900 in all) was labelled with a tag on which the locality and the name of the twig were recorded by a selected abbreviation, thus Pas A^2 indicated that the branch was from an Early Harvest Apple sent from Pennsylvania State College, and that NYI W 25 was a twig of the linden (*Tilia americana*) from Ithaca, New York. The results obtained with the twigs from the northern and southern States in the water and in the various chemical solutions, with the date and the character of the response, may be given as follows:

APPLE (Baldwin).—

Corrosive sublimate.—Twigs from Geneva, New York, showed no response in strong corrosive sublimate solution. Twigs from Amherst, Massachusetts, in weak corrosive sublimate responded on January 31 by the easing of the leaf buds; on February 3 the leaf buds had burst;

on February 4 the first leaf had unfolded; on February 11 all the leaves had unfolded; on February 14 the first leaf had withered, and on February 21 all the leaves had withered. The twigs from Lafayette, Indiana, responded by the bursting of the buds on February 3; on February 5 the first leaf had unfolded; on February 8 all the leaves had unfolded; on February 11 the first leaf had withered; on February 14 all the leaves had withered.

Copper sulphate.—Twigs of this apple from Storrs, Connecticut, did not respond. Those from Amherst, Massachusetts, responded by the bursting of the buds on February 7; on February 8 the first leaf had unfolded; on February 15 all the leaves had unfolded, while on February 18 all the leaves had withered. The twigs from Lafayette, Indiana, in weak copper sulphate solution responded on February 8 by the bursting of the buds; on February 11 the first leaf had unfolded; on February 24 the twig had gone bad.

Sodium chloride.—Twigs of the Baldwin Apple in a weak solution of common salt responded on February 1 by an easing of the buds; on February 3 the buds had burst; on February 4 the first leaf had unfolded, while by February 14 all of the leaves had withered. The twigs obtained from Lafayette, Indiana, made no response.

Ammonium nitrate.—The twigs from Lafayette, Indiana, in a strong solution of this chemical made response on February 5 by the bursting of the buds. No other response was noted.

Ammonium oxalate.—The twigs of this apple sent from New Brunswick, New Jersey, responded by the easement of the buds on January 29. No other response was noted. In weak ammonium oxalate the apple twigs from Lafayette, Indiana, made no response.

Potassium chloride.—The apple twigs from Storrs, Connecticut, in weak potassium chloride eased their buds on February 3. The buds burst on February 4; on February 5 the first leaf had unfolded; on February 11 all the leaves had unfolded, while on February 11 the first leaf had withered.

Sodium bicarbonate.—The Baldwin Apple twigs from Pennsylvania State College did not respond in a strong solution of sodium bicarbonate. The New Jersey grown twigs responded on February 3 and on February 7 the buds had burst. On February 14 all the leaves had withered; January 29 the flower buds had eased. The weak solution of this salt acted more favorably. On February 3 the leaf buds of a Connecticut twig had burst, while a Michigan grown twig responded first on January 30; while on January 31 the leaf buds and a first leaf had unfolded. January 29 witnessed the bursting of the first flower bud.

Potassium bisulphate.—The twigs from Storrs, Connecticut, kept in weak potassium bisulphate responded by the easing of the buds on February 4; on February 5 the buds had burst, and on February 7 the first leaf had unfolded. The twigs from Michigan made a slight response in this weaker solution by the bursting of the buds on February 1.

Hydrochloric Acid.—The Baldwin Apple twigs from Michigan in the weak acid solution made no response.

Acetic Acid.—No response in the strong acetic acid solution. Twigs from Storrs, Connecticut, responded by the buds easing on January 31. After the buds had burst on February 11 no other response was noted.

Nitric Acid.—No response.

Water.—The Baldwin Apple twigs from Pennsylvania State College responded on January 29 by the easement of the flower buds; on February 3 the flower and leaf buds had burst; on February 4 the flower buds had protruded from the winter bud scales. On February 18 all of the flowers were found withered. The twigs from New Brunswick, New Jersey, responded on February 1 with the easement of the leaf buds; on February 3 the leaf buds had burst; on February 5 the flower buds burst; while on February 7 the first leaf was unfolded, and on February 21 all of the leaves had unfolded. The flowers made no further response. The twigs from Geneva, New York, responded on January 31 by an easement of the buds. On February 4 the leaf buds had burst. The twigs from Storrs, Connecticut, responded as follows: February 1 leaf and flower buds eased; February 3 leaf and flower buds burst; February 4 first leaf unfolded. From this time until death no other developments were noted. The development of the twigs from Massachusetts showed a more steady course. On January 31 the buds had eased; on February 4 the buds had burst; on February 5 the first leaf had unfolded; on February 8 all the leaves had unfolded; on February 14 the first leaf had withered. The Michigan twigs responded first on January 29 with the easing of the buds; on January 31 the buds had burst; on February 1 the first leaf had unfolded; on February 4 all of the leaves had unfolded, while on February 14 the first leaf had withered and on February 18 all of the leaves had withered. The Baldwin apple twigs from Lafayette, Indiana, made response on February 4 with the bursting of the buds. On February 6 the first leaf had unfolded and on February 14 all of the twigs were dead.

APPLE (Early Harvest).—

Corrosive sublimate.—The twigs from College Park, Maryland, in

strong corrosive sublimate solution responded on February 5 with the easing of the buds; on February 7 the leaf buds had burst; on February 11 the first leaf had unfolded, while on February 14 all of the leaves had expanded. The leaves had all withered by February 21. In weak solution the buds of the twigs from Auburn, Alabama, had eased on January 31; on February 4 the leaf buds had burst, and on February 11 the first leaf had unfolded.

Copper sulphate.—The twigs from College Park, Maryland, in strong solution showed response on February 1 when the leaf and flower buds had eased; on February 4 the flower buds had burst. No other response followed. The twigs from Pennsylvania State College responded on February 18, seventeen days later than those from Maryland, but the buds remained closed without bursting. In weak solution the twigs from Auburn, Alabama, responded February 1 by the easing of the flower buds and leaf buds on February 5, and by February 15 the first leaf had unfolded. No other response.

Sodium chloride.—The buds on twigs from College Park, Maryland, in strong solution responded slightly on February 5 without any advance.

Ammonium nitrate.—The twigs from College Park, Maryland, in weak solution responded on February 1 by the easing of the buds. No other response.

Ammonium oxalate.—Twigs from College Park, Maryland, and Geneva, New York, in strong solutions of this chemical made no response. In a weak solution the twigs from Auburn, Alabama, responded by the bursting of the leaf buds on February 14 and by the expansion of the first leaf on February 15.

Potassium chloride.—In strong solutions the branches from College Park, Maryland, and Geneva, New York, made no response.

Sodium bicarbonate.—The twigs from College Park, Maryland, made no response in strong solution.

Potassium bisulphate.—Twigs from Pennsylvania State College made no response in strong solution, neither did those from Auburn, Alabama, in weak chemical.

Acetic Acid.—The twigs from Auburn, Alabama, in weak acid showed no change and eventually died.

Nitric Acid.—The buds on twigs from Auburn, Alabama, showed a slight response in weak acid by the easing of the buds. Eventually the twig died.

Chromic Acid.—The specimens from Auburn, Alabama, in weak acid made no response.

Water.—The Early Harvest apple twigs from Pennsylvania State College made a slight response by the easing of the buds on January 31. Those from Maryland burst their flower buds on February 4 and their leaf buds on February 14. The twigs from Geneva, New York, showed a more steady course of development. On February 4 the buds had eased; on February 5 the buds had burst; on February 11 the first leaf had expanded, and on February 24 all of the leaves had unfolded, some of which remained green until March 14. The only responses of the twigs from Alabama were on January 29 when the flower buds had eased, and on February 18 when the leaf buds had burst.

Apple (Maiden Blush).—

Corrosive sublimate.—In weak solution the twigs from Storrs, Connecticut, responded on February 4 when the leaf buds showed signs of swelling. On February 5 the leaf buds had burst and on February 7 the first leaf had unfolded. The twigs from Lafayette, Indiana, responded on February 4 and on February 7 the leaf buds had burst.

Copper sulphate.—The twigs from Lansing, Michigan, burst their buds on February 1 without other response.

Sodium chloride.—The buds on twigs from Storrs, Connecticut, responded on February 7 without other change. Those on twigs from Lafayette, Indiana, burst on February 14, with the expansion of the first leaf on February 15.

Ammonium nitrate.—In strong solutions of this chemical the leaf buds burst on February 3; the first leaf unfolded February 4, and the first flower bud burst on February 1 on twigs from Lansing, Michigan. The only response of twigs from Lafayette, Indiana, was on January 31 when the leaf buds burst.

Ammonium oxalate.—The buds on twigs from College Park, Maryland, responded on February 5, and on February 7 the first leaf bud had burst in strong solution. In weak solution the Connecticut twigs made no response. Those from Lafayette, Indiana, responded by the easing of the buds on January 31; bud bursting on February 3 and leaf unfolding February 11.

Potassium chloride.—No response in strong solution. The Storrs, Connecticut, twigs in weak solution responded on February 3 and the leaf buds burst on February 5. The buds of the Lafayette, Indiana, twigs responded January 29 and had burst by February 1.

Sodium bicarbonate.—The twigs in a weak solution of this chemical responded on February 5, but after that date they were at a standstill. The twigs from Indiana and Alabama made no response.

Potassium bisulphate (strong and weak).—No response of any of the twigs.

Hydrochloric Acid.—In strong acid the twigs from College Park, Maryland, made no response; those from Geneva, New York, did not. In weak solution those from Storrs, Connecticut, and Lansing, Michigan, showed no response. Those from Lafayette, Indiana, responded on February 4; on February 5 the buds had burst and on February 7 the first leaf had expanded.

Acetic Acid.—The buds on twigs from College Park, Maryland, responded on February 1 in strong acid. In weak acid the buds on twigs from Storrs, Connecticut, had burst on February 4, and by February 7 the first leaf had unfolded. The first leaf withered on February 14.

Nitric Acid.—In strong solution the twigs from College Park, Maryland, had responded by February 1. No other advance was made. In weak acid those from Lafayette, Indiana, responded on February 3 and the first leaf burst on February 4. No other change was shown.

Chromic Acid.—In strong chromic acid the twigs of the Maiden Blush apple from College Park, Maryland, responded on January 29. February 1 marks the response of the flower buds; February 3 the bursting of the leaf buds; February 7 the opening of the flowers; February 14 the opening of the first leaf and the withering of the flowers. By February 18 all the leaves had withered. In dilute chromic acid, the flower buds on twigs from Lansing, Michigan, showed response on January 29. On January 29 the flower buds had burst and on January 31 they were all closed. On February 8 the first leaf bud had burst and on February 11 the first leaf was unfolded. The leaf buds on twigs from Lafayette, Indiana, responded on January 29. The leaf buds burst on February 1 and the flower buds on February 7. The leaf buds on twigs from Auburn, Alabama, responded on February 4. The first leaf and flower buds burst simultaneously on February 11. The first leaf unfolded on February 14 and all the leaves on February 21. The first leaf withered on March 4.

Water.—The leaf buds on twigs from College Park, Maryland, responded on January 29; the leaf buds burst on February 3 and the first leaf unfolded on February 4. The first flower bud burst on February 7. The flower buds on twigs from Geneva, New York, responded on January 29. On February 3 the flower buds had burst. On January 31 the first leaf had unfolded. No other change was recorded. The leaf buds of twigs from Connecticut responded on February 4, the buds burst on February 5 and the first leaf unfolded February 11. By February 24 all the leaves had withered. The

flower buds on twigs from Michigan responded on January 29 and burst on February 3. The leaf buds responded February 1, burst February 11 together with the unfolding of the first leaf. The leaf buds on twigs from Lafayette, Indiana, responded February 1, burst on February 3; the first leaf unfolded February 4; all the leaves expanded February 6. By February 14 all the leaves had withered. The twigs from Auburn, Alabama, responded poorly by the unfolding of the first leaf on February 21.

Having described the course of development of the buds and twigs from three different varieties of apple, we may tabulate the remainder of the observations in order to shorten the descriptive account.

Apple (Red Astrachan).—

Corrosive sublimate (strong).—College Park, Maryland: Leaf buds eased February 4; leaf buds burst February 5.

Corrosive sublimate (weak).—Auburn, Alabama: Leaf buds burst February 7; first leaf unfolded February 14; all leaves unfolded February 24; first leaf withered February 15.

Copper sulphate (strong).—College Park, Maryland: No response.

Copper sulphate (weak).—Auburn, Alabama: Leaf buds eased February 7; leaf buds burst February 8; first leaf unfolded February 11; all leaves unfolded February 21; first leaf withered March 7; all leaves withered March 11.

Sodium chloride (strong).—College Park, Maryland: Leaf buds eased January 30; leaf buds burst January 31. Pennsylvania State College: First leaf unfolded February 5.

Sodium chloride (weak).—Storrs, Connecticut: Leaf buds eased January 31; leaf buds burst February 3; first leaf unfolded February 4; all leaves unfolded February 7; first leaf withered February 14; all leaves withered February 18.

Ammonium nitrate (weak).—College Park, Maryland: Leaf buds eased February 5; leaf buds burst February 7; first leaf unfolded February 11; all leaves withered February 24.

Ammonium oxalate (strong).—College Park, Maryland: Leaf buds eased February 3; flower buds eased January 29; flower buds burst February 5; flowers open February 7.

Ammonium oxalate (weak).—Storrs, Connecticut: No response.

Potassium chloride (strong).—College Park, Maryland: No response.

Potassium chloride (weak).—

	Storrs, Conn.	Lansing, Mich.
Leaf buds eased	February 3.	January 30.
Leaf buds burst	February 5.	February 1.
First leaf unfolded	February 14.	February 14.

Sodium bicarbonate (strong).—No response of twigs from College Park, Maryland, and Geneva, New York.

Sodium bicarbonate (weak).—

	Storrs, Conn.	Lansing, Mich.	Auburn, Ala.
Leaf buds eased	February 1.	....	....
Leaf buds burst	....	February 3.	February 7.
First leaf unfolded	February 4.	February 7.	February 21.

Potassium bisulphate (weak).—Storrs, Connecticut: Leaf buds eased February 1; leaf buds burst February 7; first leaf unfolded February 11. Auburn, Alabama: No response.

Hydrochloric Acid (strong).—Storrs, Connecticut: Leaf buds burst February 4.

Acetic Acid (strong).—Pennsylvania State College: No response.

Acetic Acid (weak).—

	Auburn, Ala.	Lansing, Mich.	Storrs, Conn.
Leaf buds eased	February 5.	....	....
Leaf buds burst	February 7.	January 31.	February 3.
First leaf unfolded	February 14.	....	February 4.
All leaves unfolded	February 18.	....	....
First leaf withered	February 24	....	....

Nitric Acid (weak).—

	Storrs, Conn.	Auburn, Ala.
Leaf buds eased	February 4.	February 7.
Leaf buds burst	February 5.	February 11.

Chromic Acid (weak).—Storrs, Connecticut: Leaf buds burst February 3; first leaf unfolded February 4; all leaves unfolded February 11; first leaf withered February 21; all leaves withered February 24.

Water.—

	Pennsylvania State College.	College Park, Maryland.	Geneva, New York.	Storrs, Connecticut,	Lansing, Michigan.	Auburn, Alabama
Leaf buds eased	....	Feb. 5.	....	Feb. 3.	Feb. 4.	Feb. 6.
Leaf buds burst	Jan. 30.	....	....	Feb. 4.	Feb. 6.	Feb. 11.
First leaf unfolded	Feb. 1.	Feb. 11.	Jan. 31.	Feb. 7.	....	Feb. 14.
All leaves unfolded	Feb. 7.	Feb. 18.	....	Feb. 8.	....	Feb. 21.
First leaf withered	Feb. 7.	Mar. 17.	Feb. 18.	Feb. 14.	....	Feb. 21.
All leaves withered	Feb. 21.	....	....	Feb. 24.	....	Feb. 28.
Flower buds eased	Jan. 29.	....	....	....	....	....

APPLE (Winesap).—

Corrosive sublimate (weak).—Lafayette, Indiana: Leaf buds eased February 5; leaf buds burst February 7.

Twigs from Lafayette, Indiana, in copper sulphate (weak), sodium chloride (weak), ammonium nitrate (strong), ammonium oxalate (weak), showed no response.

Those from Auburn, Alabama, in potassium chloride (weak) and sodium bicarbonate showed no response. The twigs from College Park, Maryland, in strong hydrochloric acid did not respond. Neither did those from Geneva, New York, in strong nitric acid and strong chromic acid.

Acetic Acid (strong).—College Park, Maryland: Leaf buds eased February 3; leaf buds burst February 4; first leaf unfolded February 11.

Water.—Twigs from Auburn, Alabama, did not respond.

	College Park, Maryland.	Geneva, New York.	Lafayette, Indiana.
Leaf buds burst	February 14.	February 3.	February 11.
Leaf buds unfolded	February 15.	....	....
All leaves withered	....	February 18.	....
Flower buds burst	....	February 4.	....

APPLE (York Imperial).—

Corrosive sublimate (weak).—Storrs, Connecticut: Leaf buds burst February 4.

Copper sulphate (weak).—Storrs, Connecticut: Leaf buds eased February 4; leaf buds burst February 5.

Sodium chloride (weak).—Storrs, Connecticut: Leaf buds eased February 4; leaf buds burst February 5; first leaf unfolded February 7. Amherst, Massachusetts: Leaf buds eased January 31; leaf buds burst February 4; first leaf unfolded February 5; all leaves unfolded February 11; first leaf withered February 14; all leaves withered February 21; flower buds eased February 11.

Ammonium oxalate (weak).—Storrs, Connecticut: No response.

Potassium chloride (weak).—

	Storrs, Conn.	Amherst, Mass.	Lafayette, Ind.	Auburn, Ala.
Leaf buds eased	February 1.	....	February 7.	February 14.
Leaf buds burst	February 3.	February 5.	February 11.	February 15.
First leaf unfolded	....	February 11.	February 14.	....
All leaves withered	....	February 14.	February 21.	....

Sodium bicarbonate (strong).—College Park, Maryland: No response.
Sodium bicarbonate (weak).—Auburn, Alabama: No response.

	Storrs, Conn.	Lafayette, Ind.	Amherst, Mass.
Leaf buds eased	February 3.	February 6.	January 31.
Leaf buds burst	February 4.	February 7.	....
First leaf unfolded	....	....	February 3.
First leaf withered	....	....	February 14.
All leaves withered	....	....	February 21.

Potassium bisulphate (weak).—Storrs, Connecticut, and Auburn, Alabama: No response. Lafayette, Indiana: Buds burst February 8; first leaf unfolded February 14; all leaves withered February 24.

No response was obtained in twigs from Storrs, Connecticut; Auburn, Alabama; College Park, Maryland, and Geneva, New York, in hydrochloric acid (strong and weak), acetic acid (strong) and nitric acid (strong and weak).

Acetic Acid (weak).—

	Storrs, Conn.	Lafayette, Ind.
Leaf buds eased	February 5.	
Leaf buds burst	....	February 11.
First leaf unfolded	....	February 14.

Chromic Acid (strong),—College Park, Maryland: Leaf buds eased February 14.

Chromic Acid (weak).—Auburn, Alabama: No response. Storrs, Connecticut: Leaf buds eased February 3; leaf buds burst February 4; first leaf unfolded February 7; all leaves unfolded February 14; all leaves withered February 21.

Water.—Lafayette, Indiana: Twigs gave no response.

	College Park, Maryland.	Auburn, Alabama.	Geneva, New York.	Storrs, Connecticut.	Amherst, Massachusetts.
Leaf buds eased	....	Feb. 11.	Jan. 30.	Feb. 1.	Feb. 1.
Leaf buds burst	Feb. 11.	Feb. 15.	Jan. 31.	Feb. 4.	Feb. 3.
First leaf unfolded	....	Feb. 18.	Feb. 3.	....	Feb. 7.
All leaves unfolded	....	....	Feb. 7.	....	Feb. 11.
First leaf withered	....	....	....	....	Feb. 14.
All leaves withered	Feb. 21.	....	Feb. 14.	....	Feb. 18.

CHERRY (Governor Wood).—

No response of twigs from College Park, Maryland, in strong potassium chloride, strong sodium bicarbonate, and in water.

CHERRY (Napoleon Bigarreau).—

No response of twigs from Pennsylvania State College in strong ammonium oxalate and strong hydrochloric acid. In water the flower buds were eased on January 30.

CHERRY (Morello).—

No response of the twigs from New Brunswick, New Jersey, in strong copper sulphate; of those from Pennsylvania State College in strong potassium bisulphate; of those from Amherst, Massachusetts, in weak potassium bisulphate; of those from Pennsylvania State College in strong hydrochloric acid.

Sodium chloride (strong).—New Brunswick, New Jersey: Leaf buds eased January 28.

Ammonium nitrate (weak).—Pennsylvania State College: Leaf buds eased January 28; flower buds eased January 29.

Ammonium oxalate (weak).—Amherst, Massachusetts: Leaf buds eased February 8; flower buds eased January 29; flower buds burst February 3.

Potassium chloride (strong).—New Brunswick, New Jersey: Leaf buds eased January 30; flower buds eased January 30.

Sodium bicarbonate (weak).—Amherst, Massachusetts: Flower buds eased January 29; flower buds burst February 3.

Nitric Acid (strong).—Pennsylvania State College: Leaf buds eased January 31; flower buds eased January 29.

Water.—

	Pennsylvania State College.	New Brunswick, N. J.	Amherst, Mass.
Leaf buds eased	....	January 28.	January 28.
Leaf buds burst	February 5.	....	February 1.
First leaf withered	....	....	February 14.
All leaves withered	....	....	February 21.
Flower buds eased	January 29.	January 30.	January 29.
Flower buds burst	February 1.	February 5.	February 1.

PEACH (Early Crawford).—

No response as tabulated below:

Corrosive sublimate (strong).—College Park, Maryland.

Copper sulphate (strong).—College Park, Maryland.

Sodium chloride (strong).—College Park, Maryland.

Ammonium nitrate (weak).—College Park, Maryland.

Water.—College Park, Maryland.

Copper sulphate (weak).—Auburn, Alabama.

Ammonium oxalate (weak).—Auburn, Alabama.

Water.—Auburn, Alabama.

Hydrochloric Acid (strong).—Geneva, New York.

Water.—Geneva, New York.

Ammonium nitrate (strong).—Auburn, Alabama: Leaf buds eased January 29; leaf buds burst January 31; first leaf unfolded February 7.

PEACH (Late Crawford).

Twigs from the stations indicated in a previous table were placed in solutions of corrosive sublimate (weak), copper sulphate (weak), sodium chloride (weak), ammonium nitrate (strong), ammonium oxalate (weak), potassium chloride (strong and weak), sodium bicarbonate (strong and weak), potassium bisulphate (strong), hydrochloric acid (strong), acetic acid (strong), without showing any response. The twigs in water eased their flower buds on January 31 and on February 5 the flower buds had burst.

PEACH (Oldmixon Free).—

No response of any description of the twigs from the various stations noted in the table at the beginning of the experimental record in any of the various experimental fluids except water. This and the immediately preceding series indicates that the peach is peculiarly sensitive to the action of such chemicals as were used. In water the twigs from College Park, Maryland, responded as follows: Leaf buds eased February 1; leaf buds burst February 7; flower buds burst February 3.

PEAR (Duchess de Angouleme).—

Corrosive sublimate (weak).—Storrs, Connecticut: Leaf buds eased February 1.

Sodium chloride (weak).—Storrs, Connecticut: Leaf buds burst February 1; flower buds burst February 4.

Potassium chloride (strong).—College Park, Maryland: Flower buds burst January 29.

Potassium chloride (weak).—Storrs, Connecticut: Leaf buds eased February 4; flower buds eased January 29.

Sodium bicarbonate (strong).—College Park, Maryland: Leaf buds eased February 4.

Potassium bisulphate (strong).—College Park, Maryland: Leaf buds burst January 29.

Acetic Acid (strong).—New Brunswick, New Jersey: Flower buds eased January 29.

Chromic Acid (strong).—New Brunswick, New Jersey: Leaf buds burst February 3; flower buds burst January 29.

Water.—

	College Park, Maryland.	New Brunswick, New Jersey	Geneva, New York.	Storrs, Connecticut.	Lansing, Michigan.
Leaf buds eased	Jan. 31.	Feb. 3.	Jan. 31.	....	Feb. 1.
Leaf buds burst	Feb. 4.	Feb. 4.	Feb. 1.	....	Feb. 3.
First leaf unfolded	Feb. 7.	Feb. 5.	....	....	Feb. 6.
All leaves withered	....	Feb. 14.	....	....	....
Flower buds eased	....	....	....	Jan. 29.	....
Flower buds burst	....	Jan. 29.	....	....	....

PEAR (Bartlett).—

No response was observed in twigs from stations as follows: Geneva, New York, twigs in strong corrosive sublimate; New Brunswick, New Jersey, twigs in strong copper sulphate; Storrs, Connecticut, twigs in copper sulphate (weak), and in weak ammonium oxalate; Lansing, Michigan, twigs in weak sodium bicarbonate.

Corrosive sublimate (weak).—Storrs, Connecticut: Leaf buds eased January 31; leaf buds burst February 4; first leaf unfolded February 7; first leaf withered February 11.

Copper sulphate (weak).—Amherst, Massachusetts: First leaf unfolded February 5; first leaf withered February 11.

Sodium chloride (strong).—New Brunswick, New Jersey: Leaf bud burst February 7.

Sodium chloride (weak).—Storrs, Connecticut: Leaf buds eased February 1; leaf buds burst February 5. Lansing, Michigan: Leaf buds burst January 31; first leaf unfolded February 4; all leaves withered February 24; flower buds eased January 29; flower buds burst February 3; flowers closed February 13.

Potassium chloride (weak).—Storrs, Connecticut: Leaf buds eased February 4; leaf buds burst February 5. Lansing, Michigan: First leaf unfolded February 3.

Sodium bicarbonate (strong).—University of Pennsylvania: Leaf buds eased February 4; leaf buds burst February 5.

Sodium bicarbonate (weak).—Amherst, Massachusetts: Leaf buds eased January 21; leaf buds burst February 3.

Potassium bisulphate (weak).—Lansing, Michigan: Leaf buds eased

February 1; leaf buds burst February 3; flower buds burst January 28.

Acetic Acid (strong).—University of Pennsylvania: Leaf buds eased February 1; leaf buds burst February 3; first leaf unfolded February 4; all leaves withered February 8.

Nitric Acid (strong).—University of Pennsylvania: Leaf buds eased January 29; leaf buds burst January 31; first leaf unfolded February 3; all leaves withered February 8.

Chromic Acid (strong).—University of Pennsylvania: First leaf unfolded February 3; all leaves unfolded February 4; first leaf withered February 8; all leaves withered February 14; flower buds eased January 29; flower buds burst January 30; flowers closed January 31; first flower withered February 11.

Water.—

	University of Penna.	New Brunswick, N. J.	Geneva, N. Y.	Storrs, Conn.	Lansing, Mich.	Amherst, Mass.
Leaf buds eased	....	....	....	....	Feb. 3.	....
Leaf buds burst	....	....	....	Feb. 3.	....	....
First leaf unfolded	Feb. 3.	Feb. 1.	....	Feb. 7.	....	Feb. 1.
All leaves unfolded	....	....	....	....	....	Feb. 3.
First leaf withered	....	....	....	....	....	Feb. 14.
All leaves withered	Feb. 11.	....	....	Feb. 24.	....	Feb. 18.
Flower buds eased	....	....	Jan. 29.	....	....	....
Flower buds burst	Jan. 29.	Jan. 28.	....	....	....	Jan. 29.
Flowers closed	Jan. 31.	Jan. 29.	....	....	....	Jan. 31.
Flowers open	Feb. 4.	....	....	....	....	Feb. 3.
First flower withered	Feb. 5.	....	....	....	....	Feb. 7.
All flowers withered	Feb. 7.	....	....	....	....	Feb. 7.

PEAR (Clapp Favorite).—

No response was observed with twigs from New Brunswick, New Jersey, in strong copper sulphate; with twigs from Storrs, Connecticut, in weak ammonium oxalate.

Corrosive sublimate (strong).—New Brunswick, New Jersey: Leaf buds eased February 1; leaf buds burst February 3; first leaf unfolded February 7; all leaves unfolded February 11; first leaf withered February 14; all leaves withered February 24.

Sodium chloride (strong).—New Brunswick, New Jersey: Leaf buds eased February 1.

Sodium chloride (weak).—Storrs, Connecticut: Leaf buds eased January 31; leaf buds burst February 3.

Ammonium nitrate (weak).—New Brunswick, New Jersey: Leaf

buds eased February 3; leaf buds burst February 5; first leaf unfolded February 7; first leaf withered February 11; all leaves withered February 21.

Potassium chloride (weak).—Storrs, Connecticut: Leaf buds eased February 5.

Sodium bicarbonate (weak).—Storrs, Connecticut: Leaf buds eased January 31; leaf buds burst February 3; first leaf withered February 8; flowers buds burst January 25. Lansing, Michigan: Leaf buds burst February 1; flower buds eased January 27.

Potassium bisulphate (weak).—Storrs, Connecticut: Leaf buds eased January 30; leaf buds burst February 1; first leaf unfolded February 4; first leaf withered February 7; all leaves withered February 8. Lansing, Michigan: Leaf buds eased January 30; first leaf unfolded February 3; flower buds burst January 29; flowers closed January 29; flowers open January 31; all flowers withered February 5.

Hydrochloric Acid (strong).—Storrs, Connecticut: Leaf buds eased February 1; leaf buds burst February 4.

Acetic Acid (weak).—Storrs, Connecticut: Leaf buds eased February 3; leaf buds burst February 4; first leaf unfolded February 8; first leaf withered February 8; all leaves withered February 11.

Nitric Acid (weak).—Storrs, Connecticut: Leaf buds burst February 5.

Chromic Acid (weak).—Storrs, Connecticut: Leaf buds eased February 1; leaf buds burst February 3; first leaf unfolded February 7; all leaves unfolded February 8.

Water.—

	New Brunswick, New Jersey.	Storrs, Connecticut.	Lansing, Michigan.
Leaf buds eased	January 30.	January 31.	January 30.
Leaf buds burst	February 4.	February 5.	January 31.
First leaf unfolded	February 7.	February 7.	....
All leaves unfolded	February 8.	February 11.	....
First leaf withered	....	February 14.	....
All leaves withered	February 24.	....	....

PEAR (Flemish Beauty).—

Corrosive sublimate (weak).—Storrs, Connecticut: Leaf buds eased February 1; first leaf unfolded February 4; all leaves withered February 14. Lafayette, Indiana: Leaf buds eased February 3; leaf buds burst February 5; first leaf unfolded February 8; all leaves unfolded February 11; all leaves withered February 14.

Copper sulphate (weak).—Storrs, Connecticut: Leaf buds eased February 3; leaf buds burst February 4.

Sodium chloride (weak).—Lafayette, Indiana: Leaf buds burst February 3; first leaf unfolded February 7; all leaves withered February 24.

Storrs, Connecticut: Leaf buds eased January 31; leaf buds burst February 3; first leaf unfolded February 7; first leaf withered February 11; all leaves withered February 14.

Ammonium oxalate (weak).—Storrs, Connecticut: No response. Lansing, Michigan: Leaf buds eased February 4.

Potassium chloride (weak).—Storrs, Connecticut: Leaf buds eased February 4. Lansing, Michigan: Leaf buds burst February 3; first leaf unfolded February 5; all leaves withered February 11; flower buds eased January 29. Lafayette, Indiana: No response.

Sodium bicarbonate (weak).—Storrs, Connecticut: Leaf buds burst February 1; first leaf unfolded February 7; all leaves withered February 21. Lafayette, Indiana: Leaf buds eased February 1.

Potassium bisulphate (weak).—Storrs, Connecticut: No response. Lafayette, Indiana: Leaf buds eased January 31; leaf buds burst February 1.

Hydrochloric Acid (strong).—Storrs, Connecticut: No response.

Acetic Acid (weak).—Lafayette, Indiana: No response.

Water.—New Brunswick, New Jersey: No response. Storrs, Connecticut: Leaf buds eased January 31; leaf buds burst February 3. Lansing, Michigan: Leaf buds eased February 1; leaf buds burst February 3. Lafayette, Indiana: Leaf buds eased February 1; leaf buds burst February 3; first leaf unfolded February 4; all leaves unfolded February 21; first leaf withered February 21.

PEAR (Kieffer).—

Corrosive sublimate (weak).—Storrs, Connecticut: Leaf buds eased February 4; leaf buds burst February 7. Lansing, Michigan: First leaf unfolded January 31; all leaves unfolded February 4; first leaf withered February 8; all leaves withered February 11; flower buds eased January 27; flower buds burst January 28; flowers open January 29; first flower withered February 3. Lafayette, Indiana: Leaf buds eased January 31; leaf buds burst February 3; first leaf unfolded February 5; all leaves unfolded February 8; first leaf withered February 11; all leaves withered February 14.

Copper sulphate (weak).—Storrs, Connecticut: No response. Lansing, Michigan: Leaf buds eased January 31; leaf buds burst February

1. Lafayette, Indiana: Leaf buds burst February 1; first leaf unfolded February 4.

Sodium chloride (weak).—Storrs, Connecticut: No response. Lafayette, Indiana: Leaf buds eased February 4; leaf buds burst February 7.

Ammonium nitrate (strong).—Lafayette, Indiana: Leaf buds eased January 30; leaf buds burst January 31; first leaf unfolded February 4; first leaf withered February 8; all leaves withered February 21. Auburn, Alabama: Leaf buds eased January 31; leaf buds burst February 4; first leaf unfolded February 7; all leaves unfolded February 11; first leaf withered February 14; all leaves withered February 24.

Ammonium nitrate (weak).—State College, Pennsylvania: Leaf buds eased January 31; leaf buds burst February 1; all leaves withered February 24. Ithaca, New York: No reaction.

Ammonium oxalate (strong).—New Brunswick, New Jersey: Leaf buds eased January 30; leaf buds burst February 3. Ithaca, New York: No reaction.

Ammonium oxalate (weak).—Lafayette, Indiana: Leaf buds eased January 31; leaf buds burst February 3; first leaf unfolded February 4; first leaf withered February 7; all leaves withered February 24.

Potassium chloride (strong).—College Park, Maryland, and Ithaca, New York: No response.

Potassium chloride (weak).—Twigs from Storrs, Connecticut, Lafayette, Indiana, and Auburn, Alabama, showed no response.

Sodium bicarbonate (strong).—Twigs from College Park, Maryland, and Ithaca, New York, showed no response. Those from New Brunswick, New Jersey, responded by easement of leaf buds on January 30.

Sodium bicarbonate (weak).—Storrs, Connecticut: No response. Lafayette, Indiana: Leaf buds eased January 29; leaf buds burst January 31; first leaf unfolded February 1; all leaves unfolded February 3.

Potassium bisulphate (strong).—Twigs from College Park, Maryland, and Ithaca, New York, showed no response.

Potassium bisulphate (weak).—Storrs, Connecticut: No response. Lansing, Michigan: Leaf buds burst January 29; first leaf unfolded February 3. Lafayette, Indiana: Leaf buds burst February 3; first leaf unfolded February 5; all leaves unfolded February 8; first leaf withered February 11; all leaves withered February 21.

Hydrochloric Acid (strong).—Twigs from College Park, Maryland, Ithaca, New York, Storrs, Connecticut, showed no response in this chemical.

Hydrochloric Acid (weak).—Lansing, Michigan: Leaf buds eased January 29; leaf buds burst January 31. Lafayette, Indiana: Leaf buds eased January 30; leaf buds burst January 31: first leaf withered February 7; all leaves withered February 8.

Acetic Acid (strong).—College Park, Maryland: No response. New Brunswick, New Jersey: Leaf buds eased February 1; leaf buds burst February 4; first leaf unfolded February 7.

Acetic Acid (weak).—Storrs, Connecticut: No response. Lafayette, Indiana: Leaf buds eased February 1; leaf buds burst February 4.

Nitric Acid (strong).—Storrs, Connecticut: No response.

Chromic Acid (strong).—State College, Pennsylvania: Leaf buds eased January 30; leaf buds burst February 3; leaf buds unfolded February 4; first leaf withered February 14; all leaves withered February 24.

Water.—Pennsylvania State College: Leaf buds eased February 1; burst February 3; unfolding of first leaf February 8. New Brunswick, New Jersey: Leaf buds eased February 1; leaf buds burst February 4; first leaf unfolded February 8; all leaves unfolded February 11; first leaf withered February 14; all leaves withered February 18. Ithaca, New York: Leaf buds eased February 3; leaf buds burst February 4. Storrs, Connecticut: Leaf buds eased February 1; leaf buds burst February 4; first leaf unfolded February 11. Lansing, Michigan: Leaf buds eased January 29; leaf buds burst February 1. Lafayette, Indiana: Leaf buds burst February 6. Auburn, Alabama: Leaf buds eased February 3; leaf buds burst February 4. College Park, Maryland: Leaf buds eased February 1; leaf buds burst February 3; first leaf unfolded February 7; flower buds eased January 28; flower buds burst January 29.

Pear (Seckel).—

Corrosive sublimate (strong).—University of Pennsylvania: Leaf buds burst February 1; first leaf unfolded February 4. College Park, Maryland: Leaf buds eased February 3; leaf buds burst February 4; first leaf unfolded February 7; all leaves unfolded February 11; first leaf withered February 14; all leaves withered February 24. Ithaca, New York: Leaf buds burst February 14; first leaf unfolded February 18.

Corrosive sublimate (weak).—Lafayette, Indiana: No response. Lansing, Michigan: Leaf buds eased January 31; leaf buds burst February 1; first leaf unfolded February 3; all leaves unfolded February 7; first leaf withered February 7; all leaves withered February 11.

Copper sulphate (strong).—No response shown in twigs from the University of Pennsylvania; College Park, Maryland; Ithaca, New York.

Copper sulphate (weak).—Amherst, Massachusetts: Leaf buds eased February 1; leaf buds burst February 4; all leaves withered February 14.

Sodium chloride (strong).—No response in twigs from University of Pennsylvania and Ithaca, New York. College Park, Maryland: Leaf buds eased February 3; leaf buds burst February 7.

Sodium bicarbonate (weak).—Amherst, Massachusetts: Leaf buds eased February 5; leaf buds burst February 7. Lafayette, Indiana: No response.

Potassium bisulphate (strong).—New Brunswick, New Jersey: Leaf buds eased January 31; leaf buds burst February 1.

Potassium bisulphate (weak).—Amherst, Massachusetts: Leaf buds burst February 5. Lafayette, Indiana: No response.

Acetic Acid (strong).—New Brunswick, New Jersey: Leaf buds eased January 31; leaf buds burst February 1.

Acetic Acid (weak).—Lansing, Michigan: Leaf buds burst January 30; first leaf unfolded February 1; all leaves unfolded February 4. No response of twigs from Lafayette, Indiana, University of Pennsylvania, Ithaca, New York, New Brunswick, New Jersey, in ammonium nitrate (strong), weak ammonium nitrate, strong and weak ammonium oxalate, weak and strong potassium chloride and strong sodium bicarbonate.

Water.—

	University of Penna.	College Park, Md.	New Brunswick, N. J.	Ithaca, N. Y.	Geneva, N. Y.	Lansing, Mich.	Amherst, Mass.
Leaf buds eased	Jan. 31.	Feb. 4.	Feb. 1.	....	Feb. 3.	....	....
Leaf buds burst	....	Feb. 5.	Feb. 3.	Feb. 28.	....	Jan. 29.	....
First leaf unfolded	Feb. 3.	Feb. 8.	Feb. 8.	....	....	Feb. 1.	Feb. 7.
All leaves unfolded	Feb. 4.	....	Feb. 11.	....	....	....	Feb. 8.
First leaf withered	Feb. 11.	....	Feb. 14.	....	....	....	Feb. 14.
All leaves withered	Feb. 14.	....	Feb. 18.	....	....	....	Feb. 18.

The twigs from Amherst, Massachusetts, further showed the easement of the flower buds on January 29; burst on January 31; were open February 4 and withered by February 5.

PIN OAK (*Quercus palustris*).—

The twigs of the pin oak from Pennsylvania State College, College Park, Maryland, University of Pennsylvania, and Lansing, Michigan, showed no response in strong sodium chloride, weak ammonium nitrate, strong potassium chloride, strong sodium bicarbonate and weak nitric acid, while those in weak chromic acid burst their leaf buds on February 15.

Water.—University of Pennsylvania: First leaf unfolded February 24; flower buds burst January 27; flowers opened January 28. Pennsylvania State College: No response, as also the twigs from Lansing, Michigan.

Tulip Poplar (*Liriodendron tulipifera*).[3]—

No response in any of the solutions, with the following few exceptions: Potassium bisulphate (weak)—Leaf buds eased February 5. Acetic acid (weak) with twigs from Auburn, Alabama—Leaf buds burst February 7.

Water.—Lansing, Michigan: Leaf buds eased February 4; leaf buds burst February 6; first leaf unfolded February 18. Lafayette, Indiana: Leaf buds eased February 7; leaf buds burst February 8.

Carolina Poplar (*Populus monilifera*).—

Corrosive sublimate (strong).—No response in twigs from University of Pennsylvania, New Brunswick, New Jersey, and Ithaca, New York.

Corrosive sublimate (weak).—Lansing, Michigan: Leaf buds eased February 4. Auburn, Alabama: No response.

Copper sulphate (strong).—University of Pennsylvania: Leaf buds eased February 7; leaf buds burst February 14. New Brunswick, New Jersey: First leaf unfolded February 11.

Copper sulphate (weak).—Storrs, Connecticut: Leaf buds eased February 7; leaf buds burst February 8. Auburn, Alabama: Leaf buds eased February 7; leaf buds burst February 8; first leaf unfolded February 11; all leaves unfolded February 21; first leaf withered March 7; all leaves withered March 11. The twigs from Lansing, Michigan, and Lafayette, Indiana, showed no reaction.

Sodium chloride (strong).—University of Pennsylvania: Leaf buds eased February 7; leaf buds burst February 11. Twigs from Ithaca, New York, showed no response.

Sodium chloride (weak).—Storrs, Connecticut: Leaf buds eased February 7. Lansing, Michigan: Leaf buds eased February 4.

---

[3] The localities are given in the table at the beginning of the experimental data

Ammonium nitrate (strong).—Lansing, Michigan: No response. Lexington, Kentucky: Leaf buds eased February 7; leaf buds burst February 8. Auburn, Alabama: Leaf buds eased February 3; leaf buds burst February 4; first leaf unfolded February 7; all leaves unfolded February 18; first leaf withered February 15; all leaves withered February 24.

Ammonium nitrate (weak).—University of Pennsylvania: Leaf buds eased February 7; leaf buds burst February 15. Ithaca, New York: Leaf buds eased February 4; leaf buds burst February 7. Twigs from College Park, Maryland, and Ithaca, New York, showed no response.

Ammonium oxalate (weak).—No response in twigs from Storrs, Connecticut, Lansing, Michigan, and Auburn, Alabama.

Potassium chloride (strong).—University of Pennsylvania: Leaf buds eased February 4; leaf buds burst February 8; first leaf unfolded February 14; all leaves unfolded February 24; first leaf withered February 24. Pennsylvania State College: Leaf buds eased February 3; leaf buds burst February 5. New Brunswick, New Jersey: No response.

Potassium chloride (weak).—Storrs, Connecticut: Leaf buds eased February 3; leaf buds burst February 4; first leaf unfolded February 14; all leaves unfolded February 18; first leaf withered February 21; all leaves withered February 24. Lexington, Kentucky: Leaf buds burst February 3. Auburn, Alabama: First leaf unfolded February 4; first leaf withered February 14; all leaves withered February 15. Twigs from New Brunswick, New Jersey, Lansing, Michigan, Storrs, Connecticut, Lafayette, Indiana, Auburn, Alabama, Lexington, Kentucky, showed no response in strong sodium bicarbonate, weak potassium bisulphate, weak hydrochloric acid.

Sodium bicarbonate (weak).—Storrs, Connecticut: Leaf buds burst February 1. Lexington, Kentucky: Leaf buds eased February 7; leaf buds burst February 7. Auburn, Alabama: Leaf buds burst February 14; first leaf unfolded February 14; first leaf withered March 14.

Acetic Acid (weak).—Auburn, Alabama: Leaf buds burst February 8; first leaf unfolded February 8.

Nitric Acid (weak).—Storrs, Connecticut: Leaf buds eased February 7. Auburn, Alabama: No response.

Chromic Acid (weak).—Storrs, Connecticut: Leaf buds eased January 30; leaf buds burst January 31; first leaf unfolded February 11; all leaves unfolded February 21; first leaf withered February 28; all leaves withered March 4. Auburn, Alabama: No response.

Water.—University of Pennsylvania: Leaf buds eased February 7; leaf buds burst February 14; first leaf unfolded February 28; first leaf withered February 24, while this branch showed green leaves on March 14. Pennsylvania State College: Leaf buds burst February 14; first leaf unfolded February 14. New Brunswick, New Jersey: Leaf buds burst February 7; first leaf unfolded February 8; all leaves unfolded February 28; roots appeared on March 14 and the branch was still green. Lansing, Michigan: Leaf buds eased February 4. Lexington, Kentucky: Leaf buds eased February 6, as also those from Auburn, Alabama.

RED MAPLE (*Acer rubrum*).—

The only responses obtained with branches of the red maple from the localities noted in the table at the beginning of the experimental data were with those from Lansing, Michigan, placed in sodium bicarbonate. The flower buds eased on January 25; flower buds burst on January 27; first flower withered on January 29; all the flowers withered on January 30.

The twigs from New Brunswick, New Jersey, in water show their leaf buds burst on February 11; on February 15 the first leaf had unfolded. The leaf buds on branches from Ithaca, New York, burst on February 18.

HORSE CHESTNUT (*Æsculus hippocastanum*).—

Corrosive sublimate (weak).—Storrs, Connecticut: Leaf buds eased January 31; leaf buds burst February 21.

Copper sulphate (weak).—Storrs, Connecticut: Leaf buds eased January 30; leaf buds burst February 4.

Sodium chloride (strong).—University of Pennsylvania: Leaf buds eased February 1; leaf buds burst February 11. Pennsylvania State College: Leaf buds eased January 31; leaf buds burst February 7; first leaf unfolded February 8; all leaves unfolded February 14; first leaf withered February 18; all leaves withered February 24.

Sodium chloride (weak).—Storrs, Connecticut: Leaf buds eased January 31; leaf buds burst February 3; first leaf unfolded February 7; first leaf withered February 14; all leaves withered February 18.

Ammonium nitrate (weak).—Ithaca, New York: Leaf buds eased February 1; leaf buds burst February 7.

Ammonium oxalate (strong).—University of Pennsylvania: Leaf buds eased January 31; leaf buds burst February 11. Ithaca, New York: Leaf buds eased February 14.

Ammonium oxalate (weak).—Storrs, Connecticut: Leaf buds eased January 31; leaf buds burst February 3. Lansing, Michigan: Leaf buds eased February 3; leaf buds burst February 4; first leaf unfolded February 7; flower buds burst February 5; first flower withered February 14; all flowers withered February 18.

Potassium chloride (strong).—University of Pennsylvania: Leaf buds eased February 1; leaf buds burst February 8.

Potassium chloride (weak).—Storrs, Connecticut: Leaf buds eased January 29; leaf buds burst January 31; first leaf unfolded February 7; all leaves unfolded February 18; all leaves withered February 21. Lansing, Michigan: Leaf buds eased February 4; leaf buds burst February 7.

Sodium bicarbonate (strong).—University of Pennsylvania: Leaf buds eased February 1; leaf buds burst February 7. Pennsylvania State College: Leaf buds eased January 30; leaf buds burst January 31; first leaf unfolded February 11. New Brunswick, New Jersey: Leaf buds eased February 4; leaf buds burst February 7; first leaf unfolded February 11; first leaf withered February 14; all leaves withered February 18.

Sodium bicarbonate (weak).—Lansing, Michigan: Leaf buds eased February 4; leaf buds burst February 7; first leaf unfolded February 11; all leaves withered February 18. Lexington, Kentucky: Leaf buds eased February 3; leaf buds burst February 7; first leaf unfolded February 11; all leaves unfolded February 21; first leaf withered February 21; all leaves withered February 24.

Potassium bisulphate (strong).—New Brunswick, New Jersey. Leaf buds eased February 4; leaf buds burst February 5; first leaf unfolded February 7. Geneva, New York: Leaf buds eased January 30; leaf buds burst February 3.

Potassium bisulphate (weak).—Lansing, Michigan: Leaf buds eased February 3; leaf buds burst February 7; first leaf unfolded February 11. Lexington, Kentucky: Leaf buds eased February 4; leaf buds burst February 7; first leaf unfolded February 11; all leaves unfolded February 21; all leaves withered February 24.

Hydrochloric Acid (weak).—Lansing, Michigan: Leaf buds eased February 3; leaf buds burst February 11.

Acetic Acid (strong).—New Brunswick, New Jersey: Leaf buds eased February 5; leaf buds burst February 8.

Acetic Acid (weak).—Lexington, Kentucky: Leaf buds eased February 4; leaf buds burst February 7.

Water.—

	University of Penna.	Penna. State College.	New Brunswick, N. J.	Ithaca, N. Y.	Geneva, N. Y.	Storrs, Conn.	Lansing, Mich.	Lexington, Ky.
Leaf buds eased	Fb. 1.	Fb. 1.	Fb. 1.	Ja. 31.	Fb. 1.	Ja. 31.	Fb. 4.	Fb. 4.
Leaf buds burst	Fb. 7.	....	Fb. 7.	Fb. 4.	Fb. 4.	Fb. 4.	Fb. 8.	....
First leaf unfolded	Fb. 11.	Fb. 4.	Fb. 8.	Fb. 7.	Fb. 7.	Fb. 8.	Fb. 11.	Fb. 11.
All leaves unfolded	Fb. 21.	Fb. 14.	Fb. 14.	Fb. 11.	....	Fb. 14.	....	Fb. 14.
First leaf withered	Fb. 21.	Fb. 18.	Fb. 15.	Fb. 18.	Fb. 14.	Fb. 14.	....	....
All leaves withered	Fb. 24.	Fb. 24.	Fb. 18.	Fb. 24.	Fb. 18.	Fb. 21.	....	....

The flower buds of twigs from the University of Pennsylvania and Geneva, New York, in water burst on February 15 and February 5 respectively.

Golden Forsythia (*Forsythia viridissima*).—

Corrosive sublimate (strong).—Pennsylvania State College: Leaf buds eased January 31; flower buds burst February 3; flowers open February 7; first flower withered February 8.

Corrosive sublimate (weak).—Storrs, Connecticut: No response. Lexington, Kentucky: Leaf buds eased January 30; flower buds eased January 30; flower buds burst January 31; flowers opened February 1; first flower withered February 5; all flowers withered February 7. No response with twigs from Pennsylvania State College, Lexington, Kentucky, and Ithaca, New York, in weak and strong copper sulphate and strong sodium chloride.

Sodium chloride (weak).—Storrs, Connecticut: Flower buds eased January 27. Lansing, Michigan: Flowers opened January 28; first flower withered February 3.

Ammonium nitrate (strong).—Lexington, Kentucky: Leaf buds eased January 29; leaf buds burst January 31.

Ammonium nitrate (weak).—Pennsylvania State College: Leaf buds eased January 29; leaf buds burst January 31; first leaf unfolded February 3; all leaves unfolded February 5; first leaf withered February 7; all leaves withered February 24.

Ammonium oxalate (strong).—Pennsylvania State College: Leaf buds eased February 13; leaf buds burst February 4. Branches from College Park, Maryland, and Ithaca, New York, gave no reaction.

Ammonium oxalate (weak).—Storrs, Connecticut: No response. Lexington, Kentucky: Leaf buds eased February 3.

Potassium chloride (strong).—University of Pennsylvania: Leaf buds eased February 1. Branches from College Park, Maryland and Ithaca, New York, gave no response.

Potassium chloride (weak).—Storrs, Connecticut: No response. Lansing, Michigan: Leaf buds eased February 1; leaf buds burst February 4; first leaf unfolded February 11; all leaves withered February 18.

Sodium bicarbonate (strong).—University of Pennsylvania: Leaf buds eased January 31. Ithaca, New York: No response.

Sodium bicarbonate (weak).—Storrs, Connecticut: No response. Lexington, Kentucky: Leaf buds eased January 31. No response was obtained with branches from New Brunswick, New Jersey, Ithaca, New York, Storrs, Connecticut, Lexington, Kentucky, and Geneva, New York, in weak sodium bicarbonate, strong potassium bisulphate, weak potassium bisulphate, strong hydrochloric acid, strong and weak acetic acid, strong and weak nitric acid, weak chromic acid.

Hydrochloric Acid (strong).—University of Pennsylvania: Leaf buds eased February 1.

Acetic Acid (weak).—Lansing, Michigan: Leaf buds eased January 29; leaf buds burst February 8.

Nitric Acid (weak).—Lansing, Michigan: Leaf buds eased January 29; leaf buds burst January 31.

Chromic Acid (weak).—Lansing, Michigan: Leaf buds burst January 29; first leaf unfolded January 30; all leaves unfolded February 18.

Water.—

	University of Penna.	Penna. State College.	New Brunswick, N. J.	Lansing, Mich.	Ithaca, N. Y.	Geneva, N. Y.	Lexington, Ky.
Leaf buds eased	....	Jan. 30.	Jan. 28.	Jan. 29.	....	Jan. 28.	....
Leaf buds burst	Jan. 27.	Feb. 1.	....	....	Feb. 11.	....	Jan. 29.
First leaf unfolded	Jan. 29.	Feb. 1.	Jan. 29.	Feb. 1.	....	Feb. 7.	....
All leaves unfolded	Jan. 31.	....	Jan. 31.	....	....	Feb. 8.	Feb. 3.
First leaf withered	Feb. 21.	....	....	....	....	....	....
All leaves withered	Feb. 28.	....	Feb. 24.	....	Feb. 24.	Feb. 24.	Feb. 24.
Flower buds eased	....	....	Jan. 27.	....	....	Jan. 29.	....
Flower buds burst	....	....	....	Jan. 25.	Jan. 29.	Jan. 31.	Jan. 30.
Flowers closed	Jan. 31.	....	....	....	Jan. 29.	....	....
Flowers opened	Jan. 31.	....	....	Jan. 27.	Jan. 30.	Feb. 1.	Jan. 31.
First flower withered	Feb. 4.	....	....	Jan. 28.	Feb. 5.	Feb. 5.	Feb. 7.
All flowers withered	....	....	....	Jan. 31.	Feb. 7.	....	Feb. 8.

LINDEN (*Tilia americana*).—

Corrosive sublimate (strong).—University of Pennsylvania: Leaf buds eased February 4.

Copper sulphate (strong).—No response in twigs from University of Pennsylvania.

Copper sulphate (weak).—No response exhibited by Storrs, Connecticut; Lansing, Michigan; Lexington, Kentucky.

Sodium chloride (strong).—Ithaca, New York: No response. University of Pennsylvania: Leaf buds eased February 7; leaf buds burst February 11.

Sodium chloride (weak).—Storrs, Connecticut: No response.

Ammonium nitrate (strong).—Lansing, Michigan: Leaf buds eased February 7. Lexington, Kentucky: Leaf buds eased February 18. No response of twigs from University of Pennsylvania; Ithaca, New York; Storrs, Connecticut; Lexington, Kentucky; Lansing, Michigan; Lafayette, Indiana; Pennsylvania State College; New Brunswick, New Jersey, and Geneva, New York, in weak ammonium nitrate, strong and weak ammonium oxalate, strong and weak potassium chloride, strong and weak sodium bicarbonate, strong potassium bisulphate, strong hydrochloric acid, weak acetic acid, strong and weak nitric acid, strong chromic acid.

Ammonium oxalate (weak).—Lexington, Kentucky: Leaf buds eased February 7; leaf buds burst February 11.

Potassium chloride (strong).—University of Pennsylvania: Leaf buds eased February 3; leaf buds burst February 7.

Sodium bicarbonate (weak).—Leaf buds eased February 5.

Acetic Acid (strong).—University of Pennsylvania: Leaf buds eased February 4.

Water.—University of Pennsylvania: Leaf buds eased February 4; leaf buds burst February 7; first leaf unfolded February 11; all leaves unfolded February 14; first leaf withered February 14; all leaves withered February 24. New Brunswick, New Jersey: Leaf buds eased February 7; leaf buds burst February 11. Ithaca, New York: Leaf buds burst February 7. Storrs, Connecticut: Leaf buds eased February 7. Lansing, Michigan: Leaf buds eased February 4; leaf buds burst February 6. Lexington, Kentucky: Leaf buds eased February 4.

YULAN MAGNOLIA (*Magnolia conspicua*).—

Corrosive sublimate (strong): University of Pennsylvania: Flower buds eased January 27. No response of twigs from University of Pennsylvania or New Brunswick, New Jersey, in strong ammonium oxalate, potassium chloride, sodium bicarbonate (strong), potassium bisulphate (strong) and chromic acid (strong).

Water.—University of Pennsylvania: Leaf buds burst January 31; first leaf unfolded February 3; all leaves unfolded February 7; all

leaves withered February 18; flower buds eased January 25; flowers opened January 27; first flower withered January 29; all flowers withered January 30. New Brunswick, New Jersey: Leaf buds eased February 3; leaf buds burst February 5; all leaves withered February 14. Lafayette, Indiana: No response.

Conclusions Based on Experiments.

The experiments of the second year corroborate those of the first year in many particulars. First, it will be noticed that in every case where the twigs responded, they followed the sequence already established among the branches from the same locality. In the first experiments, the phenologic sequence was established by contrasting the development of plants out of doors with those treated experimentally in the greenhouse, and it was found, as before emphasized, that the bud development in chemical solutions followed the same order as out of doors. The experiments of the second year go to prove the same thing. However, we know that in general pear trees blossom earlier than apple trees; that *Forsythia* flowers earlier than the horse chestnut; that the male catkins of the Carolina poplar appear earlier than the flowers of the linden and the oak throughout the Eastern United States at large.

By correspondence with the stations from which the twigs were obtained the following phenologic data was secured that shows the sequence of bud development:[4]

Amherst, Massachusetts.—1, Morello Cherry; 2, Baldwin Apple; 3, York Imperial Apple; 4, Bartlett Pear; 5, Seckel Pear.

Ithaca, New York.—1, Red Maple; 2, Forsythia viridissima; 3, Carolina Poplar; 4, Kieffer Pear; 5, Seckel Pear; 6, Horse Chestnut.

Geneva, New York.—1, Early Crawford Peach; 2, Duchess de Angouleme Pear; 3, Maiden Blush Apple; 4, Seckel Pear; 5, York Imperial Apple; 6, Baldwin Apple; 7, Red Astrachan Apple; 8, Bartlett Pear; 9, Winesap Apple.

Pennsylvania State College (average for ten years).—1, Forsythia viridissima; 2, Horse Chestnut; 3, Morello Cherry; 4, Carolina Poplar; 5, Tulip Poplar; 6, Kieffer Pear; 7, Pin Oak; 8, Linden.

College Park, Maryland.—1, Forsythia viridissima; 2, Early Crawford Peach; 3, Oldmixon Peach; 4, Late Crawford Peach; 5, Kieffer Pear; 6, Duchess de Angouleme Pear; 7, Seckel Pear; 8, Red Astrachan

[4] Replies were obtained from Lafayette, Indiana, and New Brunswick, New Jersey, but these stations were unable to furnish any phenologic data. No replies were obtained from the stations in Connecticut, Michigan and Alabama.

Apple; 9, Early Harvest Apple; 10, Maiden Blush Apple; 11, York Imperial Apple.

Lexington, Kentucky.—1, Tulip Poplar; 2, Oldmixon Free Peach; 3, Carolina Poplar; 4, Horse Chestnut; 5, Linden.

This general sequential development is preserved in the experimental liquids. The same phenomenon with reference to the action of poisons was emphasized in the experiments of the second year. As the data will show, buds were eased and many burst by the stimulating action of the various chemicals. In some instances the leaves unfolded, flower buds opened and such leaves and flowers reached their normal size. This was notably the case with flowers of *Forsythia viridissima* (Pennsylvania State College) in strong corrosive sublimate solution, with the leaves of the Seckel pear (College Park, Maryland) in the same solution, with the leaves and flowers of the Kieffer pear (from Michigan) in the weak corrosive sublimate, with the leaves of *Populus monilifera* (Auburn, Alabama) in weak copper sulphate solution, with the Bartlett pear flowers (Amherst, Massachusetts) in weak copper sulphate, with the York Imperial apple (Amherst, Massachusetts) in weak sodium chloride, with the horse chestnut (Pennsylvania State College) leaves in strong sodium chloride, with the York Imperial apple (Amherst, Massachusetts) leaves in weak sodium chloride, with the red maple (Lansing, Michigan) flowers in weak sodium chloride, with the *Forsythia* (Lexington, Kentucky) flowers in strong ammonium nitrate, with the *Populus monilifera* (Auburn, Alabama) leaves in the same solution. In the weak ammonium nitrate solution, the leaves of the *Forsythia* twigs from Pennsylvania State College reached full size, as did those of *Populus monilifera* from Philadelphia in strong potassium chloride and the flowers of the Bartlett pear (Lansing, Michigan) in weak potassium chloride. The flowers of Clapp Favorite and Kieffer pears opened when the twigs were placed in weak potassium bisulphate, as also the leaves of the Kieffer pear twigs from Lafayette, Indiana. In weak acetic acid solution, the leaves of the Red Astrachan apple (Auburn, Alabama) opened fully wide. The flowers of the Maiden Blush (College Park, Maryland) opened when the twigs were placed in the weak chromic acid solution. But eventually, with but few exceptions, all of the twigs succumbed, many after the first green leaf had been formed. The strong solutions of copper sulphate, potassium bisulphate, hydrochloric and nitric acids seemed to be arrestive and deadly, because very few of the twigs even responded when placed in these solutions.

These results, it seems to the writer, are corroborative of the principle

that response is not arrested until the poison has actually penetrated and killed the living cells, thus putting a stop to the suctional activity and responsive power of the living cells. The poisons enumerated, being perhaps more easily conducted, act at once in killing the cells, which with other poisons are stimulated long before they are eventually killed. Bose (*loc. cit.*, 383) has demonstrated this differential activity of poisonous solutions in a number of his experiments. Among various solutions of salt, some are physiologically neutral in their effects; of these potassium nitrate may be taken as an example. Others, again, like a strong solution of sodium chloride, act as excitatory agents. The application of this last reagent is known to initiate rhythmic excitation in animal tissues. Similar effects have been shown to be brought about by this reagent in the case of *Biophytum* and *Desmodium*. Thus in a strong solution of potassium nitrate we have a reagent whose physiologic action is more or less neutral, while its osmotic action is pronounced, and in a strong solution of common salt we have an agent which is both excitatory and osmotic at the same time. If, then, we apply $K\ NO^3$ solution to the base of a cut stem, placed in the shoshungraph (Bose's apparatus), water will be osmotically withdrawn from the plant in opposition to normal suction, and the normal suctional rate will be somewhat reduced. On the application of copper sulphate, the suctional movement, Bose found, was quickly arrested, and this was followed almost immediately by a slight movement in the negative direction; showing that by some spasmodic contraction water was expelled from the tissue. This phase was succeeded by an almost complete arrest of suction, there being now only the feeblest ascensional movement. Within a short period after this, on washing off the poisonous reagent, it was found that the arrest had been temporary only, suction being renewed at the rate of eleven instead of the normal fifteen cubic mm. per minute. The poison was applied once more and allowed to act for thirty-six hours. The arrest was then found to be permanent—that is to say, the substitution of fresh water induced no revival of response, the plant being killed throughout. It is interesting to note that the twigs experimented with at the University of Pennsylvania responded after a much longer time interval than thirty-six hours, as noted in the experimental data above.

It will be noted also that the sequence between northern and southern grown twigs was preserved in the experimental liquids. If the results obtained in the chemical solutions are contrasted with those in the water, it will be found that the buds on branches obtained from

northern localities responded much more quickly than did those from southern localities. Thus in water the leaf buds of the Red Astrachan apple from Storrs, Connecticut, burst on February 4; those from Lansing, Michigan, on February 6, and those from Auburn, Alabama, on February 11—a difference of a week between the more northern and the more southern localities. The leaf buds of the York Imperial apple burst in water on January 31 from Geneva, New York;[5] February 3 from Amherst, Massachusetts; February 4 from Storrs, Connecticut; February 11 from College Park, Maryland, and February 15 from Auburn, Alabama. A reference to the experimental data will show practically the same sequence throughout, the buds on northern grown twigs always opening before those on southern grown ones. The sequence of the bud development in the chemical solutions proceeded as above indicated for the twigs in water. The buds on twigs of the same species, where comparison is possible, from northern localities opened first in the same chemical and those of southern localities followed as indicated below:

Weak Corrosive sublimate (Kieffer Pear).—

	Storrs, Conn.	Lafayette, Ind.
Leaf buds eased	February 4.	January 31.
Leaf buds burst	February 7.	February 3.

Weak Copper sulphate (Maiden Blush Apple).—

	Lansing, Mich.	Auburn, Ala.
Leaf buds eased	....	February 7.
Leaf buds burst	February 1.	February 8.

Weak Sodium chloride (York Imperial Apple).—

	Amherst, Mass.	Storrs, Conn.
Leaf buds eased	January 31.	February 4.
Leaf buds burst	February 4.	February 5.
First leaf unfolded	February 5.	February 7.

Strong Ammonium nitrate (Kieffer Pear).—

	Lafayette, Ind.	Auburn, Ala.
Leaf buds eased	January 30.	January 31.
Leaf buds burst	January 31.	February 4.
First leaf unfolded	February 4.	February 7.

[5] Geneva, New York, although geographically south of Amherst, Massachusetts, is probably climatically more northern.

Weak Potassium chloride (York Imperial Apple).—

	Storrs, Conn.	Auburn, Ala.
Leaf buds eased	February 1.	February 14.
Leaf buds burst	February 3.	February 15.

Strong Sodium bicarbonate (*Æsculus hippocastanum*).—

	University of Pennsylvania.	Penna. State College.	New Brunswick, N. J.
Leaf buds eased	February 1.	January 30.	February 4.
Leaf buds burst	February 7.	January 31.	February 7.
First leaf unfolded	....	February 11.	February 11.

Weak Sodium bicarbonate (Red Astrachan Apple).—

	Storrs, Conn.	Auburn, Ala.
Leaf buds eased	February 1.	....
Leaf buds burst	....	February 7.
First leaf unfolded	February 4.	February 21.

—— (Clapp Favorite Pear).—

	Storrs, Conn.	Lansing, Mich.
Leaf buds eased	January 31.	....
Leaf buds burst	February 3.	February 1.

—— (*Populus monilifera*).—

	Storrs, Conn.	Lexington, Ky.	Auburn, Ala.
Leaf buds eased	....	February 7.	....
Leaf buds burst	February 1.	February 7.	February 14.
First leaf unfolded	....	....	February 14.

—— (*Æsculus hippocastanum*).—

	Lansing, Mich.	Lexington, Ky.
Leaf buds eased	February 4.	February 3.
Leaf buds burst	February 7.	February 7.
First leaf unfolded	February 11.	February 11.

In this case the buds developed coincidently from widely separated localities upon a European forest tree. Is this an evidence that *Æsculus hippocastanum* is not acclimated, or an evidence that as a more plastic species that it is more thoroughly so. Yet in the next experiment there is a difference.

Strong Potassium bisulphate (*Æsculus hippocastanum*).—

	Geneva, N. Y.	New Brunswick, N. J.
Leaf buds eased	January 30.	February 4.
Leaf buds burst	February 3.	February 5.

Weak Potassium bisulphate (Clapp Favorite Pear).—

	Lansing, Mich.	Storrs, Conn.
Leaf buds eased	January 30.	January 30.
Leaf buds burst	....	February 1.
First leaf unfolded	February 3.	February 4.

—— (Kieffer Pear).—

	Lafayette, Ind.	Lansing, Mich.
Leaf buds eased	February 3.	....
Leaf buds burst	....	January 29.
First leaf unfolded	February 5.	February 3.

—— (*Æsculus hippocastanum*).—

	Lansing, Mich.	Lexington, Ky.
Leaf buds eased	February 3.	February 4.
Leaf buds burst	February 7 .	February 7.
First leaf unfolded	February 11.	February 11.

The same coincidence of dates will be noticed with this tree as noted above. The response is more rapid with the more northern tree than with the more southern, but the subsequent development runs parallel as to the dates at which the various manifestations of development occur.

Weak Hydrochloric Acid (Kieffer Pear).—

	Lansing, Mich.	Lafayette, Ind.
Leaf buds eased	January 29.	January 30.
Leaf buds burst	January 31.	January 31.

Strong Acetic Acid (*Æsculus hippocastanum*).—

	University of Pennsylvania.	New Brunswick, N. J.
Leaf buds eased	January 31.	February 5.
Leaf buds burst	February 7.	February 8.

Weak Acetic Acid (Red Astrachan Apple).—

	Storrs, Conn.	Auburn, Ala.
Leaf buds eased	....	February 5.
Leaf buds burst	February 3.	February 7.
First leaf unfolded	February 4.	February 14.

Weak Nitric Acid (Red Astrachan Apple).—

	Storrs, Conn.	Auburn, Ala.
Leaf buds eased	February 4.	February 7.
Leaf buds burst	February 5.	February 11.

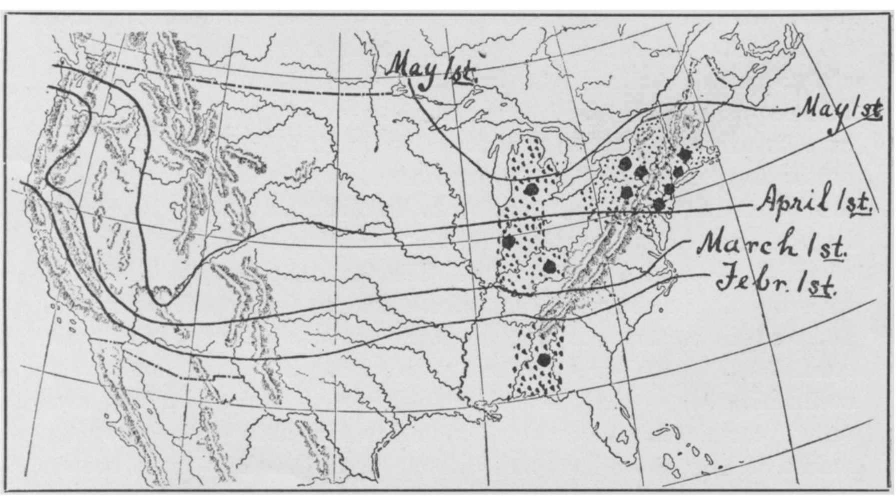
Weak Chromic Acid.—

	Lansing, Mich.	Auburn, Ala.[6]
Leaf buds eased	....	February 4.
Leaf buds burst	February 8.	February 11.
First leaf unfolded	February 11.	February 14.

The fact that there is such a difference between the time when the leaf and flower buds of the same variety and species of fruit and forest trees open is an index of the extent of their acclimatization. The native trees have, since their migration from the original forest centre, been acclimated to their new localities of growth, while the introduced fruit trees since their introduction to America have become similarly ameliorated to the American climate, so that they react in nature and in the experimental culture solutions exactly as do the native plants.

Bearing of Experimental Data on the Advent of Spring.

The climatic differences between the north and the south, representing the amount of acclimatization which each species has had to adopt, may be demonstrated by a study of the advent of spring. The temperature of 42.8° F. (6° C.) is that at which the protoplasmic contents of the ordinary plant find the limits of their activity. The advent of spring may be considered as taking place at the approach of an isotherm one degree higher, or 43.8° F. This isotherm, progressing steadily in



Map illustrating the advance of the isotherm of spring (43.8° F.), as well as the regions (........) and stations (●) from which the experimental twigs were obtained.

[6] Started two days later.

its advance across the United States, is illustrated in the accompanying map which was constructed from the recorded mean temperatures for 15 years from 1870–1885.[7] This line may be regarded as the edge of spring. In the Gulf States there is no true advent of spring. On February 1 the isotherm in question crosses the United States from the vicinity of Cape Hatteras on the east to the north of El Paso, then turns northwestward and reaches the Pacific coast some distance north of San Francisco. The advance on the first of successive months is illustrated by the map.

Spring may be said to begin in our most northern locality, Lansing, Michigan, about May 1. Auburn, Alabama, lies below the isotherm of February 1. We therefore have a difference of three months in the awakenment of vegetation under the influence of the advent of spring conditions. Yet in our experimental cultures no such great discrepancy existed, because the heat of the greenhouse is more uniform (not so fluctuating), and yet, notwithstanding the fact that the interval between the successive events is shortened, nevertheless the same phenologic sequence is maintained as described above. The difference of three months in the advent of spring between the most northern and the most southern of our localities indicates the real amount of acclimatization of the same species and race growing in the different places from which the experimental material was obtained. That is, the growing season of trees and shrubs is very much abbreviated compared with the growing season in more southern situations. Three months difference is a very appreciable amount between the northern and southern States, and the fact that such fruit trees as the Maiden Blush apple and the Kieffer pear can be grown in Michigan and Alabama is noteworthy as an instance of acclimatization of the most pronounced type. In Alabama the growing season is about nine months long, from February 1 to November 1. In Michigan the growing season begins May 1 and is completed by the beginning of October, a length of about five and a half months. The fact that many of the fruit trees mentioned above did not take kindly to the American climate, and that they afterwards became adapted to its wide range of climatic conditions is proof of their acclimatization. Yet some doubt that acclimatization occurs. A writer in *Forest Leaves* (XI : 108) says that "Trees are fixed, almost inflexible, in their habits. For centuries, indeed as long as we have record, each species has kept in its beaten ways, insisting on the same average of temperature and refusing to

[7] Harrington, Mark W.: The Advent of Spring. *Harper's Magazine*, May, 1894.

grow where this could not be, seeking and occupying certain kinds of soil and demanding certain amounts of moisture and avoiding situations where these were wanting." In connection with the experiments which have preceded, some experimental data from other sources should be given in order to prove that organisms can be acclimated, that is can be inured or habituated to conditions at first injurious to them. A referencc to the short bibliography of acclimatization at the end of this paper will enable the investigator to obtain the additional evidence of acclimatization which it is not possible to review. The experimental data for animals and plants is here given.

General Experimental Work on Acclimatization.

Among invertebrates Loew[8] has found in Owen's Lake, California, the alkaline waters of which contain among other things 2.5% of Na_2CO_3, numerous living infusoria, Copepoda, larvæ of Ephydra and molds. Again the vinegar eel, *Rhabditis aceti,* lives in a 4% solution of acetic acid, although this strength is usually fatal: *e. g.*, a 0.23% solution of acetic acid kills the tentacles of *Drosera,* according to Darwin. Beudant accustomed fresh-water animals to salt water. He used *Lymnea, Physa, Planorbis, Ancyclus, Paludina* and some other fresh-water mollusks. He began in April by putting these organisms into a 1% NaCl solution, and, continuing to add salt slowly, by September many of these withstood a 4% solution, a solution which kills animals suddenly subjected to it. He performed the reverse experiment upon marine mollusca, bringing them to live in fresh water by gradually diluting the medium. According to MacDougal,[9] Lopriori found that while the streaming movements of protoplasm were inhibited by exposure to an atmosphere of one part oxygen and four parts carbon dioxide, yet if the plant were first exposed to a mixture of 25 parts of oxygen and 75 of carbon dioxide for a time, it might then be brought successively into atmospheres containing 80, 85, 90, 95 and even 100 parts of the gas without immediate injury. Organisms can be acclimatized to extreme temperatures. Davenport (*loc. cit.*, 249) cites illustrations of both. Few active organisms can withstand a temperature of over 45° C., and for whole groups like Cœlenterata, marine mollusca, crustacea and fishes 40° is a point of death. There are plant and animal organisms that carry on their life processes in hot springs. Simple plants like *Chroococcus, Nostoc, Anabœna, Leptothrix, Oscillaria,* etc.,

[8] Davenport, C. B.: *Experimental Morphology,* p. 28.
[9] *Textbook of Plant Physiology,* 57.

exist in springs where the temperature ranges from 45° to 93° C. Rotifers and Anguillulidæ were found in the Carlsbad Springs of Bohemia at a temperature of 44° to 54°; *Cypris balnearia* occurred in water 45° to 50.5° and *Stratiomys* larva at 69° in a hot spring in Colorado. But the experiments of Dallinger are remarkable illustrations of gradual acclimatization. He kept Flagellata in a warm oven for many months. Beginning with a temperature of 15.6° C. he employed the first four months in raising the temperature 5.5°; this, however, was not necessary, since the rise to 21° can be made rapidly, but for success in higher temperatures he found it best to proceed slowly from the beginning. When the temperatures had been raised to 23° the organisms began drying, but soon ceased, and after two months the temperature was raised half a degree more and eventually to 25.5°. Here the organisms began to succumb again, but finally after several years of treatment Dallinger succeeded in rearing the organisms in a temperature of 70° C. The same acclimatization to cold may be shown. Thus the swarm spores of a marine alga were liberated when the temperature of the water was between 1.5° and 1.8° C.

We can exemplify this kind of acclimatization in the higher plants. Our treatment of the twigs from various localities demonstrates that this kind of acclimatization was operative in the past with each tree species. Sweet peas raised in Calcutta from seed imported from England rarely blossom and never yield seed; plants from French seed flower better, but are still sterile; but those raised from Darjeeling seed (originally imported from England) both flower and seed profusely, according to Wallace.[10] Speaking of the introduction of the Sea Island cotton into the United States, Wight[11] says that (*Gossypium barbadense* and *G. vitifolium*) they were with much difficulty introduced into North America owing to the shortness of the summer season. The former (Sea Island), indeed, could not be established until a fortunate occurrence of a very mild winter permitted the roots to live through it and produce an early crop of fresh shoots in the spring. These bore and ripened, the seed of which was found sufficiently hardy to resist the cold of spring and matured a crop of excellent cotton in the course of the succeeding autumn. Indian corn develops local varieties with extreme readiness, but they seldom succeed when transferred even short distances, at least until time enough for acclimatization has elapsed. E. Davenport sent a standard white Illinois corn, ripening in about

[10] *Encyclopedia Britannica*, article "Acclimatization."

[11] Watt, Sir George: *The Wild and Cultivated Cotton Plants of the World*, 1907, p. 272.

120 days and capable of maximum yields (75 bushels per acre), to be grown in Michigan, Wisconsin, Maine and Mississippi. In Maine it failed to ripen, but at all other points it ripened in about 100 days, producing small, inferior ears. That it should hurry through its period of growth at the north was not surprising, but that it should do so in the south is unaccountable.[12] The season of maize varies from six months in the elevated plains of Santa Fé in South America to four months in the middle United States and two and one-half months in the rainy lake district northwest of Lake Superior.[13] Peach trees from central Georgia blossom ten to twelve days later in Virginia and Maryland than do those of the same variety from New Jersey or New York. As peach trees are propagated by buds we may regard the Georgia and New Jersey trees, being of the same variety, as parts of the same individual. The foregoing citations indicate that acclimatization does occur, and that in the case of the experimental twigs the differences in the time of the bud development illustrates that acclimatization has taken place to the extent of a variation in habit as to their seasonal development, emphasized in the acclimatization of the cotton, corn and peach previously described.

The response of the buds in the chemical solutions was an immediate one, and at a season of the year when all of the twigs from widely separated stations (north and south) were in a dormant condition. The advantage of these experiments in demonstrating the above conclusions is marked over the growth of such trees in the forest, or in the orchard, for the reason that as to temperature all of the twigs were exposed equally to the same amount, and those placed in the pure water were under practically the same conditions, while the chemical solutions provided enough of different conditions under experimental control which would produce alterations in the time and method of response, if such could be produced by experimental means. The results have already been summarized.

Bibliography.

Bailey, L. H.: Survival of the Unlike. 1896 : 320–333. Acclimatization: Does it Occur?

Bose, Jagadis Chunder: Plant Response as a Means of Physiological Investigation, 1906: 361, 382–383, 386–387.

Cannon, W. A.: Acclimatization of Plants. The Plant World. XI: 113–114, May, 1908.

Carlier, M. A.: Mémoire sur l'Acclimatement des Races en Amérique. Paris. 1867, pp. 55.

---

[12] Davenport, E.: *Principles of Breeding*, 1907, p. 222.
[13] Bailey, L. H.: *Survival of the Unlike*, 1896, p. 329.

DARWIN, CHARLES: Animals and Plants under Domestication.
——Origin of Species. 1859: 112.
DAVENPORT, CHARLES B.: Experimental Morphology. 1897: 27, 85, 249.
DAVENPORT, EUGENE: Principles of Breeding. 1907: 222, 255, 257, 260, 308–316.
FOREST LEAVES: Trees Cannot be Acclimatized. XI: 108. February, 1908.
HARSHBERGER, JOHN W.: Vegetation of the Yellowstone Hot Springs. American Journal of Pharmacy. LXIX: 625.
HARRINGTON, MARK W.: The Advent of Spring. Harper's Monthly Magazine. May, 1894, p. 874.
MACDOUGAL, D. T.: Textbook of Plant Physiology. 1901: 20, 56, 92.
——Influence of Altitude and Climatic Factors upon Vegetation: Acclimatization 5th Year Book Carnegie Institution of Washington. 1907: 121.
MORGAN. THOMAS H.: Evolution and Adaptation. 1903: 319.
PFEFFER, W.: Pflanzenphysiologie, 1897–1904. Accomodation Begrenztheit derselben, II: 81, 90, 246; an Concentrationen, I: 415; II: 128, 137; an Gifte, II: 243, 247, 337; an Sauerstoffpressung, I: 548, 551; II: 131; an Temperatur, II: 91, 292, 302; an Temperatur, Gifte, Concentrationen ist nicht erblich, II: 243, 337.
SCHIMPER, A. F. W.: Pflanzengeographie auf physiologischer Grundlage, 1898: 55–58, with bibliography on page 60.
VERNON, H. M.: Variation in Animals and Plants. 1903: 378.
WALLACE, ALFRED R.: Article Acclimatization in Encyclopedia Britannica, I (1878): 84–90.
WATT, SIR GEORGE: The Wild and Cultivated Cotton Plants of the World. 1907: 272, 328.
WOODRUFF, MAJOR CHARLES E.: The Effects of Tropical Light on White Men. 1905: 321.
WOODS, A. F.: Plant Pathology. Science, New Ser., XXVI: 541–543. Oct. 25, 1907.